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SPILLOVER FROM THE HAVEN: CROSS-BORDER EXTERNALITIES OF PATENT BOX REGIMES WITHIN MULTINATIONAL FIRMS *

Thomas Schwab, Maximilian Todtenhaupt

ABSTRACT: In this paper, we analyze the cross-border effects of patent box regimes that reduce the tax rate on income from intellectual property. We argue that the tax cut in one location of a multinational enterprise may reduce the user cost of capital for the whole group if profit shifting is possible. This spillover effect of the foreign tax cut raises domestic R&D investment. We test this mechanism by combining information on patents, firm ownership and specific characteristics of patent box regimes. Empirical results from a micro-level analysis suggest that patent box regimes without a nexus requirement (patent havens) induce positive cross-border externalities on R&D activity within multinational groups. For firms with cross-border links, the implementation of a foreign patent haven increases domestic research activity by about 2.3% per implied tax rate differential. Furthermore, our findings suggest that patent boxes generate negative spillovers on average patent quality. This has important implications for international tax policy and the evaluation of patent box regimes.

JEL Codes: F23, H25, O31

Keywords: Patent box, spillover, corporate taxation, innovation

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1 Introduction

Many governments have recognized the importance of technological progress and corporate innovation for domestic productivity growth. Fostering research and development (R&D) activity of firms is therefore one of the key objectives when designing tax systems. An important instrument in this field are patent box regimes. Patent boxes allow firms to exempt a large share of profits related to intangible assets (mainly patents)[1] from taxation and thus reduce the effective tax rate on these profits. They differ substantially in their design, in particular with regard to the type of patents that are taxed at the lower rate. In a global economy with strong international links, such policies are likely to generate substantial cross-border externalities. The goal of this paper is to identify the international spillover effects of patent boxes with respect to corporate innovation.

Even though most governments claim to implement patent boxes mainly to facilitate *domestic* R&D activity, the emergence of these regimes has raised several concerns. Not surprisingly, the cross-border externalities that we investigate in this paper are at the heart of many of these issues. First, it is not certain that patent boxes actually boost new R&D projects and thus increase the overall level of corporate innovation. In response to the implementation of a more favorable tax regime in one location, firms may merely relocate existing research activity. Such a beggar-thy-neighbor effect is well-known for input-related R&D tax incentives (Wilson, 2009). Second, the economic role of patent boxes is heavily debated. In the best case, these regimes eliminate a market failure by increasing the net return of R&D to a level that better reflects the positive externalities that arise due to knowledge spillovers. In the worst case, patent boxes distort the allocation of R&D investment. Finally, patent box regimes may affect tax revenue. If a patent transfer is used as a cross-border profit shifting vehicle, patent boxes reduce tax revenues in countries with higher effective tax burdens and potentially also in the patent box countries themselves because of the lower tax rate. However, if they spur innovation that raises future profits, tax revenue may actually increase in the long-run.

Determining the sign and size of cross-border externalities of patent boxes is thus important to characterize the role of such regimes in an international context. In our paper, we analyze these externalities using micro-level data for European firms. We link ownership information for a large number of firms to R&D output. The latter is measured as the number of granted patent applications per firm and year. Cross-border links are established via multinational companies. We identify the spillover effect of patent boxes on R&D activity by estimating the response of a firm to the exogenous patent box implementation in the location of one of its affiliates.[2] As we are interested in cross-border effects of patent boxes rather than their domestic impact, we focus on the research activity of firms that are located in countries without a patent box regime.

[1]Some patent boxes also allow for the inclusion of trade marks or other intellectual property.
[2]See Figure 4 in the Appendix for a graphical illustration of this concept.

In our analysis, we differentiate between patent boxes with and without nexus requirement. The former only applies the reduced tax rate if at least part of the research activity has been carried out in the respective country. In contrast, the latter also taxes patents at the favorable rate that have been generated elsewhere. This is usually done by including existing and acquired patents in the patent box which provides firms with a simple profit shifting opportunity: They conduct R&D at the location of their choice and then transfer the resulting patent to a patent box location without nexus requirement in order to benefit from the lower tax rates there. These regimes thus lower the user cost of capital for R&D activity in the group as a whole through a mechanism that is very similar to the role of tax havens in Hong & Smart (2010). In fact, this similarity is not surprising. Countries that implement patent boxes without nexus requirement effectively become tax havens for a particular asset. Below, we thus refer to these regimes as *patent havens*. We expect patent havens to generate positive cross-border externalities on R&D activity. For patent boxes *with* nexus requirement, such an effect should not be observed since the profit shifting opportunity is limited in this case.

We test these hypotheses with a Poisson fixed effects count model which relates the number of domestically developed patents of a firm to the implementation of a foreign patent box while controlling for various location-, firm- and group-specific variables that might drive innovation activity. Our estimation results suggest that the implementation of a foreign patent haven (no nexus requirement) raises R&D activity from about one patent every three years to about one patent every one and a half years. We capture the treatment intensity by interacting the implementation indicator with the implied tax rate difference between firm and affiliate location and find that the patent haven implementation leads to an increase of R&D activity by 2.3% per percentage point of this difference. For patent boxes with nexus requirement, we find negative, and much smaller cross-border externalities. However, the estimated coefficients are not significant.

These findings are robust to controlling for domestic tax-related input incentives such as super-deductions and credits. They also pertain when we adjust the patent count for heterogeneity in the patent quality. We further ensure robustness by conducting a number of sample checks with regard to the structure and activity of the corporate group. In addition, we replicate our results using different estimation methods such as propensity score matching and coarsened exact matching as well as an event-study design. In an extension, we show that the output related tax incentive provided by patent boxes transmits to the structure of R&D inputs.

We also find that both types of patent box regimes reduce the average patent quality in related firms abroad. This result can be explained by the spatial sorting of patents according to their profitability which is similar to the sorting mechanism of firms with different levels of productivity in Melitz *et al.* (2004). Nexus patent boxes probably lead to the reallocation of the most profitable patents while patent havens allow the firm to realize more but also less profitable R&D projects.

Our analysis contributes to the large literature that relates tax policy to R&D activity. In particular, researchers have established a link between corporate taxation and investment in R&D (Mamuneas & Nadiri, 1996; Bloom *et al.*, 2002; Wilson, 2009), the location choice of intangible assets within multinational firms (Dischinger & Riedel, 2011; Karkinsky & Riedel, 2012; Griffith *et al.*, 2014) and the quality of patents (Ernst *et al.*, 2014). Only few papers analyze international spillovers of tax policy, but all of them rely on macro-level data of R&D activity. For example, Wilson (2009) focuses on input-related incentives and uses aggregate data on R&D spending from US states to show that a large part of the R&D increasing effect of tax credits is due to a reallocation of research activity between states. In contrast, our paper uses micro-level data to establish positive cross-border externalities of output-related tax incentives as a novel effect of tax policy on R&D.

In addition, we also contribute to the growing literature on patent box regimes. In this field, more normative analyses (e.g. Evers *et al.*, 2015) have recently been complemented by empirical studies (e.g. Bradley *et al.*, 2015). To the best of our knowledge, our paper is the first to empirically analyze cross-border externalities of patent boxes on R&D activity.

Finally, our analysis is related to the literature on tax havens. As noted above, by implementing patent boxes, the respective countries effectively become low-tax locations for intangible assets. Thus, the criticism that is put forward against tax havens (e.g. Dharmapala, 2008; Slemrod & Wilson, 2009) may also apply to patent box countries. Depending on their design, they may divert firm profits away from the location of real activity and thus erode the tax base of high-tax locations. Alternatively one could apply the more positive view of Hong & Smart (2010) and Desai *et al.* (2006). They argue that low-tax jurisdictions may be beneficial because they enable governments to implicitly differentiate between mobile and immobile firms, even if they cannot distinguish between the two types or are not willing to do so because of political reasons. As a first-order effect, allowing mobile firms to shift profits to low-tax locations lowers the user cost of capital in high-tax locations and increases investment there. The assumption underlying these arguments is that there are real responses of domestic firms to tax incentives abroad. Our empirical results suggest that such a mechanism exists with regard to investments with mobile profits such as R&D activity.

The remainder of this paper is structured as follows. Section 2 develops a stylized theoretical framework for our analysis and characterizes existing patent boxes. We explain the empirical strategy in Section 3 and describe the data collection in Section 4. Results are presented in Section 5 while Section 6 concludes.

2 Cross-border Externalities from Patent Boxes

2.1 Theoretical Framework

In this section, we set up a stylized theoretical framework to analyze the reaction of a firm's R&D activity to the introduction of a patent box in a country where one of its foreign affiliates resides. For simplicity, we consider a multinational enterprise (MNE) i that is located in country h and has an affiliate in country p. As we are interested in the cross-border spillovers of the patent box implementation, our focus is on the number of successfully realized research projects in h rather than the overall research activity in the group. The firm makes three decisions: it chooses whether or not to realize projects from a given set of potential undertakings indicated by $s = 1, ..., n_i$ and then decides on the location of R&D activity and on the location of ownership. The two location decisions do not necessarily coincide and depend on the characteristics of h and p such as R&D related fixed costs and tax rates. All three choices jointly determine the number of realized research projects in h.

Let us define the return to a research project s by $r_s = (1-t)\,\pi_s - c$ where $(1-t)\,\pi_s$ is the net profit (i.e. revenue less deductible cost after taxes) and c is some non-deductible fixed cost. The effective tax rate t and the fixed costs c are functions of the ownership and R&D location choice of the firm. c comprises items that are hard to price and usually not considered as deductible expenses such as the cost of risk-taking in R&D investments, the cost of becoming acquainted with local patenting institutions or the cost to identify suitable researchers. This type of cost may substantially differ between the two affiliate locations.

In the case of co-location of R&D activity and ownership, $t = t_l$, $c = c_l$, $l \in \{h, p\}$. Alternatively, the firm may geographically separate the R&D and the corresponding ownership right. There are various ways to do this, including the direct transfer of patent rights, contract R&D and cost sharing agreements between the two affiliates (Griffith *et al.*, 2014). Effectively, all of these arrangements result in part of the profit from the research project being taxed in a location different from the one where the R&D activity was carried out and thus have qualitatively similar consequences. The organizational form of the geographical allocation of patent rights is, however, a crucial feature for the empirical identification. We discuss this in more detail below.

For now, we assume that a share α of the profit of a research project conducted in h whose legal ownership has been assigned to p is taxed at t_p while the remaining profit is taxed in h. t is thus given by

$$t = \alpha t_p + (1-\alpha)\,t_h,\ 0 \leq \alpha \leq 1.$$

The parameter α captures the extend to which a reduction in the tax burden is inhibited both by regulations in the country of the transferor (e.g. CFC rules or exit taxes) and in the country of the recipient. The former are likely to be orthogonal to the patent box implementation while the latter are directly linked to the setup of the exploited patent box. For example, α is small if the patent box in p excludes R&D profits for projects conducted outside of p (nexus patent box). In contrast, α may be close to 1 if the patent box regime in p includes existing and acquired patents (patent haven).

Depending on the choices of the firm, the profit of a research project s is thus given by

$$\begin{aligned} r_s^h &= (1 - t_h)\,\pi_s - c_h && \text{if R\&D activity and ownership in } h, \\ r_s^{h,p} &= (1 - t_h + \alpha\Delta t)\,\pi_s - c_h && \text{if R\&D activity in } h \text{ and ownership in } p, \\ r_s^p &= (1 - t_p)\,\pi_s - c_p && \text{if R\&D activity and ownership in } p. \end{aligned}$$

where $\Delta t = t_h - t_p$. To simplify the derivation, we assume that firm i incurs higher fixed costs if it relocates its research activity to country p (i.e. $c_p > c_h$). Besides the specific characteristics of the fixed costs described above, this reflects potential reallocation costs which include the establishment of new organizational R&D structures in p and the effort for convincing researchers to move.

To compute the number of realized research projects, we assume that the firm first decides on whether or not to realize a particular project s and then simultaneously determines where to optimally locate R&D activity and legal ownership. If the two locations do not differ in the applicable tax rate $\Delta t = 0$, we have $r_s^h > r_s^{h,p}, r_s^p$ and the firm locates both legal ownership and R&D activity in h. It realizes all research projects with a positive return, that is any project s for which $\pi_s > \tilde{\pi}^h = \frac{c_h}{1-t_h}$. We can sort the gross profits of all available projects along the interval $(\underline{\pi}_i, \bar{\pi}_i)$ and define the corresponding cumulative distribution function F. The number of realized research projects of firm i is then given by $n_i\left(1 - F\left(\tilde{\pi}^h\right)\right)$.

A more realistic assumption would be to let $\Delta t \neq 0$. For simplicity we consider $\Delta t > 0$, although similar insights are obtained when the sign of the tax differential is reversed. As there are no fixed costs for separating ownership and activity, legal ownership is assigned to p in this case.[3] R&D activity is also located to p if $r_s^p > r_s^{h,p}$ or $\pi_s > \tilde{\pi} = \frac{c_p - c_h}{(1-\alpha)\Delta t}$. Again, only research projects with a positive return are realized. This implies that, if it is optimal to separate legal ownership and real activity, any project s with $\pi_s > \tilde{\pi}^* = \frac{c_h}{1-t_h+\alpha\Delta t}$ is realized. If the return is maximized by co-locating activity and ownership, the necessary gross profit threshold for s to be realized is $\pi_s > \tilde{\pi}^p = \frac{c_p}{1-t_p}$.

Let us assume for illustrative purposes that $\tilde{\pi}^p < \tilde{\pi}^* < \tilde{\pi}$.[4] The overall number of finished

[3] To make the framework more realistic, one could introduce some fixed costs to separating ownership and activity which would result in the ownership of some research projects being located in h even if $t_h > t_p$. This would make our model slightly more complicated without adding any further insights with regard to the main effect of interest.

[4] Various orders of the threshold profits are possible but yield the less interesting case where all research activity is located to p irrespective of the change in the tax rate differential.

projects is then given by $n_i (1 - F(\tilde{\pi}^*))$ with $n_i (1 - F(\tilde{\pi}))$ projects realized in p and the number of realized R&D projects of firm i in location h given by

$$P_i = n_i \left(F(\tilde{\pi}) - F(\tilde{\pi}^*) \right). \tag{1}$$

How is P_i affected by the implementation of a patent box in p? Such a regime lowers t_p and thus increases the tax differential Δt. The change in the number of realized R&D projects in h as a result of an increase in the tax differential of $d\Delta t$ is given by

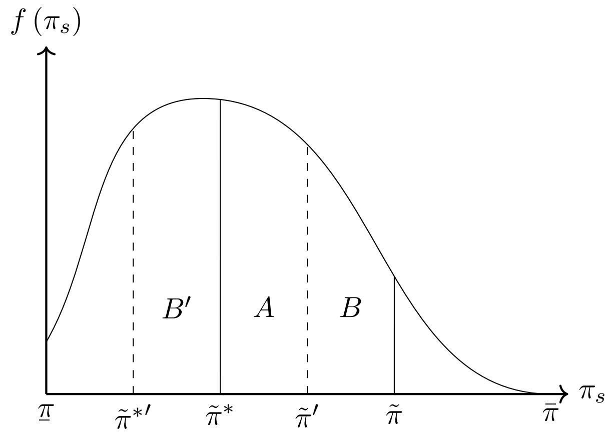
$$dP_i = n_i \left(-(1-\alpha) \frac{f(\tilde{\pi})(c_p - c_h)}{((1-\alpha)\Delta t)^2} + \alpha \frac{f(\tilde{\pi}^*) c_h}{(1 - t_h + \alpha \Delta t)^2} \right) d\Delta t. \tag{2}$$

The sign of the effect depends on how much the separation of ownership and real activity for tax purposes is inhibited by regulations. For example, if the patent box requires full nexus in location p, that is $\alpha = 0$, one would observe a negative effect of the patent box regime on R&D activity in h. In this case, cross-border reallocation of ownership (and thus profits) from h to p is not an option and the tax reduction in p does not affect the cost of R&D capital in h. Rather, activity for sufficiently profitable research projects is located to p, reducing the overall number of realized projects in h.[5] In contrast, a patent haven (no nexus requirement) has a positive effect on research output in h. Abstracting from inhibiting factors in the transferor location, we have $\alpha = 1$ in this case and thus $dP_i > 0$. As the firm is able to relocate the ownership of some projects realized in h to p, the tax cut there also reduces the user cost of R&D capital in h and increases research output.

In Figure 1 we display the effect of the patent box introduction graphically. We plot the density function of the profits of available research projects and mark the relevant cut-off profits. Initially, the firm realizes projects with profits greater than $\tilde{\pi}^*$ but allocates R&D activity of projects with profits greater than $\tilde{\pi}$ to p. The overall share of projects realized in h is thus given by $A + B$. The introduction of a patent box in p shifts $\tilde{\pi}$ and $\tilde{\pi}^*$ to $\tilde{\pi}'$ and $\tilde{\pi}^{*\prime}$, respectively, such that the share of realized projects is given by $A + B'$. The overall effect relies on a comparison of B and B' which in turn depends on the setup of the patent box. B' refers to the increase of realized R&D projects in h because of the reduction in the user cost of R&D capital captured in the second term of equation (2). B describes the R&D activity which is shifted to p because of the foreign tax cut that reduces the number of projects realized in h and is reflected in the first term of expression (2). For a patent haven α is close to 1 and $B = 0$ such that we obtain an increase in the share of R&D projects realized in h by B'. In contrast, when a nexus patent box is implemented, B and B' may neutralize each other leaving the number of research projects in h unchanged. Eventually, the direction of the effect

[5] Note that this does not necessarily imply that overall research activity of the multinational company decreases. If the tax benefits in p are large enough, the total number of patents may even increase. This occurs, however, only because the increase in research activity in p more than compensates for the decrease in h. Research activity in h always decreases.

Figure 1: Profit distribution and realized R&D projects



is an empirical question and our analysis points out that it is important to take into account the precise incentive structure of the investigated patent box.

Finally, we observe that the average profit of realized patents in h decreases with the implementation of a patent box in p. This can easily be seen when comparing the average profits of the different fractions of research projects in Figure 1. A formal analysis of this result is presented in Appendix A.3. The sign of the effect is independent of the nexus requirement of the patent box, but it follows different intuitions in each case. A patent haven lowers average patent profits because it allows R&D projects with lower profitability to be realized in h. Nexus patent boxes reduce the average profit in h because R&D activity for the most profitable projects is relocated to p. The latter mechanism is related to the one described for international trade by Melitz *et al.* (2004) who show that only the most productive firms relocate internationally. Furthermore, Haufler & Stähler (2013) show in a tax competition model, that more profitable projects sort into low-tax jurisdictions. Empirical evidence by Becker *et al.* (2012) suggests that this effect contributes significantly to the overall tax base location effect of corporate taxes. In our firm-level analysis below, we show that a similar mechanism is particularly relevant for corporate R&D activity.

2.2 Patent Boxes and Patent Location in Practice

Before empirically testing our analytical results, it is useful to relate the model to the patent boxes that exist in practice. Evers *et al.* (2015) and Alstadsater *et al.* (2015) provide a comprehensive overview of the various regimes that have been established since 2000. In Table 1 we summarize key elements of existing patent box regimes in Europe. In general, firms enjoy substantial reductions in effective tax payments when opting for these regimes but significant differences remain. Patent boxes differ in the treatment of expenses as well as in the types of intangible assets, beyond patents (e.g. trademarks, brands), they may be applied to. The extent of the tax exemption varies significantly across locations. For instance, while the tax rate on profits from patents is reduced by 35 percentage points in Cyprus, firms only enjoy a 50% exemption in Portugal which implies a decrease in the statutory tax rate of 11.25 percentage points.

Table 1: Patent box regimes in European countries

Country	Year of implementation	Corporate income tax rate (2015)	Patent box tax rate (2015)	Acquired Patents	Existing Patents
France	2000	34.0	16.8	Yes	Yes
Hungary	2003	19.0	9.5	Yes	Yes
Netherlands	2007	25.0	5.0	No	No
Spain	2008	30.0	12.0	No	Yes
Belgium	2008	34.0	6.8	No	No
Luxembourg	2008	29.2	5.8	No	No
Malta	2010	35.0	0.0	Yes	Yes
Cyprus	2012	10.0	2.5	Yes	Yes
United Kingdom	2013	20.0	12.0	No	Yes
Portugal	2014	22.5	11.3	No	No
Italy	2015	31.4	22.0	No	No
Turkey	2015	20.0	10.0	No	No
Ireland	2016	12.5	6.3	No	No

Source: IBFD; Alstadsater *et al.* (2015); Evers *et al.* (2015). Note: Ireland initially introduced a patent box regime in 1973 but abolished it in 2010. It was reintroduced in 2016.

The inclusion of a nexus requirement in patent box regimes is relevant for the sign of their cross-border externalities. Existing patent boxes again differ substantially with respect to this characteristic. In the sense of our analytical framework, a nexus requirement is a regulation that restricts the lower tax rate to income from patents for which also the underlying R&D activity has been carried out in the respective country. In this regard, it is crucial how acquired patents are treated in the patent box. Excluding them effectively precludes tax benefits from a post-generation patent transfer. Some countries directly prohibit the inclusion of acquired patents into the patent box (Spain, Portugal). Other regimes include acquired patents but require that these have been further developed to a substantial degree at the location where the resulting profits are taxed (Belgium, Ireland[6], Netherlands, United Kingdom). In Luxembourg, only patents acquired from an unrelated party outside the corporate group are included in the patent box. Patent boxes that have been implemented more recently (Italy, Ireland) comply with the Modified Nexus Approach adopted by the EU and the OECD. This approach allows only for a certain share of intellectual property income, which corresponds to the share of research conducted by the firm itself, to be included in the patent box.[7] Effectively, all of these patent boxes require that a substantial part of the research activity must be conducted in the respective country for the lower patent box rate to take effect. As a consequence, profit shifting opportunities are limited and these regimes are thus unlikely to generate positive cross-border spillovers on R&D activity.

In contrast, several patent box regimes include acquired and existing patents (France, Hungary, Malta, Cyprus) without effective restrictions.[8] Since this allows firms to conduct the actual development of the patent elsewhere and then transfer the resulting patent right to the patent box location, these regimes correspond to the patent havens described in the theoretical analysis.

As pointed out above, an institutional feature that is crucial to identify cross-border spillovers of patent boxes on R&D output is the way MNEs separate patent ownership and R&D activity. Previous studies that estimate the elasticity of legal ownership of a patent in a particular jurisdiction with respect to the applicable tax rate have argued that, if the separation of R&D activity and ownership occurs, this is done mainly through contract R&D and cost sharing arrangements whereby the patent applicant would also be the final owner (Karkinsky & Riedel, 2012; Griffith *et al.*, 2014).[9] In contrast, actual transfers of patents via intra-company sales are less attractive because of their adverse tax effects. The assumption appears sensible given that these studies cover periods when many developed countries in Europe applied CFC rules that should substantially diminish potential tax benefits of cross-border patent transfers.[10] In such an institutional environment contract R&D or cost sharing

[6]In 2008, Ireland extended the scope of its patent box to patent income resulting from R&D conducted in any EEA member state. However, the reform also imposed an upper limit of 5 mio EUR for the income to which the exemption is applied. Furthermore, income from within-company licensing was only included in the patent box if the royalties were paid by a manufacturing firm. This prohibits the setup of effective profit shifting structures through holding entities.

[7]It is also expected that from 2016 onward the other regimes will adopt this approach and change their patent box legislation accordingly.

[8]In France, the only limitation is that acquired patents must be held for at least 2 years by the acquiring company for the resulting profits to be taxed under the patent box regime.

[9]In fact, this is an important assumption for these studies to gauge the effect of corporate tax rates on patent location using patent application data because post-application transfers of patents are not recorded in the databases used in these estimations.

[10]Griffith *et al.* (2014) study patent applications from 1985 to 2005, Karkinsky & Riedel (2012) observe annual patent applications of European firms from 1995 to 2003. According to Bräutigam *et al.* (2017), Germany,

are probably attractive modes of cross-border ownership allocation.

However, the institutional environment with respect to CFC rules has changed over the last decade. The 2006 Cadbury-Schweppes ruling by the European Court of Justice (ECJ) has effectively limited the applicability of CFC rules within the European Economic Area (EEA) and, as a consequence, most member states have amended their regimes to exclude affiliates in the EEA (Bräutigam *et al.*, 2017). The remaining threat to the realization of tax benefits in cross-border patent transfers are exit taxes on the capital gains realized in these transfers. In this regard, recent ECJ rulings have stipulated that firms should at least be allowed to defer the tax payment until such gains have materialized[11] and the European Commission has asked several EU member states, including the United Kingdom, to adjust their exit tax legislation accordingly. Thus, the factors that inhibit the realization of tax benefits from cross-border transfer of patents have certainly been mitigated. In fact, a recent anonymized survey by Heckemeyer *et al.* (2015) among large multinational companies reveals that, while exit taxes are an issue of concern, MNEs still consider the selling of patents to foreign affiliates a feasible way to transfer ownership across borders.[12] A possible reason for this observation may be that it is particularly difficult for tax authorities to examine the true value of recently granted patents with no revenues attached which makes it easy to set transfer prices in such a way that MNEs can realize tax benefits from cross-border transfers. At the same time, direct patent transfers avoid problems of cost sharing or contract R&D arrangements, some of which are unrelated to taxation such as communication cost between the involved affiliates during and uncertainty with regard to the outcome of the R&D project. Furthermore, many input-related incentives for R&D (e.g. direct subsidies, tax credits) usually do not apply to research carried out as a service to another company which implies that research activity in contract R&D arrangements cannot benefit from them.

In line with Dischinger & Riedel (2011) we conclude that the post-generation transfer of intangible assets such as patents is a viable mode of ownership relocation for tax purposes. It follows that it is feasible to identify the cross-border effect of patent boxes using patent application data as the initial applicant is likely to have conducted the research project while preserving the option of a transfer for tax purposes at a later point in time. With regard to patent boxes, this view is confirmed by recent findings on patent transfers. For instance, Gaessler *et al.* (2017) estimate that the implementation of patent boxes in the recipient country that include acquired and existing patents (i.e. no nexus requirement) significantly increases the number of annual bilateral patent transfers. This is consistent with the notion that this type of patent box regimes incentivizes the separation of ownership and R&D activity as

Denmark, Finland, France, the United Kingdom, Hungary, Norway, Portugal and Sweden had CFC rules with respect to other European countries in 2003.

[11]E.g. National Grid Indus BV v Inspecteur van de Belastingdienst Rijnmond C-371/10 (NGI) and C-657/13 Verder LabTec GmbH & Co. KG v Finanzamt Hilden

[12]The survey also finds that cost sharing agreements are much less important which may reflect that they are primarily a phenomenon in MNEs with US parents due to institutional reasons (Dischinger & Riedel, 2011).

suggested above.

Even if R&D contract arrangements remain relevant, this would exert a downward bias on our estimates of cross-border spillovers. While the patent box implementation in one affiliate may actually raise R&D output in another non-patent box affiliate of an MNE, this would in some cases not be observed in the patent application data since the final applicant would be the patent box affiliate as the internal buyer of R&D services. In this case, our estimate would have to be interpreted as a lower bound of the true effect.

3 Empirical Identification

3.1 Patent Output

The goal of this paper is to assess the impact of foreign tax reductions for patent profits on domestic R&D activity. This is achieved by analyzing the cross-border effect of patent box implementations in countries where firms have foreign affiliates. Following previous studies (e.g. Blundell *et al.*, 1995; Stiebale, 2016), R&D activity of a firm is measured by its newly registered annual output of granted patents.[13] More formally, we model the number of newly granted patent applications P_{ijct} of firm i which is member of multinational group j and is located in country c in period t as a function of the availability of international patent boxes to a foreign affiliate and several control variables. We estimate a Poisson fixed effects model (see Hausman *et al.*, 1984; Wooldridge, 1999; Cameron & Trivedi, 2015) of the following form:

$$E\left(P_{ijct}\right) = exp\left(\mathbf{x'_{ijct}}\beta\right)$$
$$\text{with } \mathbf{x'_{ijct}}\beta = \alpha \cdot BOX_{jt} + \boldsymbol{\beta X_{it}} + \boldsymbol{\gamma Z_{jt}} + \boldsymbol{\delta C_{ct}} + \boldsymbol{\phi_t} + \boldsymbol{\phi_i} + u_{it}. \quad (3)$$

BOX_{jt} is a binary variable that is equal to 1 if a patent box is implemented in the country of residence of at least one of the foreign affiliates of firm i and zero otherwise. $\boldsymbol{X_{it}}$, $\boldsymbol{Z_{jt}}$ and $\boldsymbol{C_{ct}}$ are firm-, group- and location-specific characteristics. $\boldsymbol{\phi_t}$ and $\boldsymbol{\phi_i}$ capture time- and firm-specific effects.

In the estimation, we differentiate between nexus patent boxes (some nexus requirement) and patent havens (no nexus requirement). The main focus of the analysis is on the latter since we expect the strongest spillovers from these regimes. They are defined as patent boxes that include both acquired and existing patents and thus allow firms to realize tax benefits through the post-generation cross-border transfer of patents (see Table 1). In contrast, the nexus patent boxes apply the favorable rate mainly to profits from R&D activity that has been conducted in the respective location. Therefore, these patent boxes are less suitable for

[13]Granted applications are commonly used in the literature (e.g. Aghion *et al.*, 2013; Seru, 2014; Stiebale, 2016; Bena & Li, 2014) because they better capture actual research activity rather than strategic patent filing.

profit shifting via patent transfers. This means that they lower R&D cost of capital in other locations to a much smaller extent. Hence, we do not expect substantial spillovers.

We restrict our analysis to firms located in non-patent box countries. This is done for two reasons. First, external effects of patent boxes should generally not be observed at locations where a patent box is already implemented since in this case, the foreign tax regime does not provide an additional incentive. Second, as the focus of this study are spillover effects of patent boxes, patent box locations must be excluded to avoid any distorting effects of the implementation of domestic patent boxes that may or may not coincide with the implementation of patent boxes abroad.

The identification of the spillover effect relies on the assumption that, prior to the implementation of a patent box, firms with affiliates in the implementing countries are not systematically different with respect to the evolution of their R&D activity from those that do not have affiliates in these locations. We verify this below again focusing on patent havens. Most importantly, we show that even though treated and non-treated firms in our sample differ in the level of their R&D activity, the patent output trends similarly for the two groups until the occurrence of the first patent haven.

A further potential source of endogeneity is the structure of the multinational group. In principal, MNEs that comprise firms which expect an increase in their research activity have an incentive to set up a new affiliate in a country as soon as a new patent box regime is introduced there. To overcome this potential issue of reverse causality, only multinational groups without changes in their structure with respect to patent box locations are considered in the empirical analysis.[14] As a consequence, BOX_{jt} is an exogenous shock to the firm's tax incentives insofar as it is purely driven by exogenous policy changes in the residence countries of its affiliates. Identification thus hinges on the variation in the timing of the introduction of national patent box regimes.

The macroeconomic and institutional control variables include productivity measured as the log of GDP per capita, GDP growth, general research activity measured by R&D expenditures as a percentage of GDP and the corporate income tax rate. One concern with regard to our analysis may be that those countries without a patent box have instead turned to input-related tax incentives in order to remain competitive R&D locations. If these alternative incentives are the main drivers of the observed rise in domestic patenting activity, this would still hint to international spillover effects of patent boxes. Instead of a direct impact on the user cost of capital, the spillover would then be a result of policy interactions in a fiscal competition game. In order not to capture such spurious effects, we include the user cost of capital for R&D in our estimation which is a composite measure that includes input-related tax incentives such as tax credits and super-deductions for R&D activity.[15] We also control for

[14]Our results are robust to excluding only those groups with a change in ownership with respect to patent box locations within three years prior to the implementation of the respective regime.

[15]See Appendix A.3 for a detailed derivation.

several items that have been suggested to affect R&D activity on the firm level (see Stiebale, 2016), such as the number of affiliates, the age of a firm as well as the firm size measured in total assets, the working capital and the capital intensity of a firm. Finally, we include firm- and time-fixed effects to capture cross-sectional differences in the level of R&D output, as well as general time trends.

The number of patents is primarily measured as the count of annual granted patents per firm. To capture the intensity of domestic R&D activity, we also conduct our analysis using the quality-weighted number of new patents. Frequently cited patents registered at multiple patent offices and classified to contribute to many patenting classes are not only potentially more valuable (see Harhoff *et al.*, 1999), but also point to a higher R&D input (Hagedoorn & Cloodt, 2003). We construct patent quality using the composite quality indicator proposed by Lanjouw & Schankerman (2004) which is commonly used in this strand of literature (see, e.g., Hall *et al.*, 2007 and Ernst *et al.*, 2014). The composite quality indicator is derived by employing a multiple-indicator model relying on the number of forward citations, the patent family size and the number of patent classifications resulting in a relative measure for patent quality. The procedure to derive it is described in detail in Appendix A.3. For the quality-weighted number of new patents, we weight each patent by its relative quality.

3.2 Patent Quality

We also estimate the effect of a foreign patent box implementation on the average quality of new patents of a firm to test our theoretical predictions with regard to the cross-border effect of patent boxes on the quality of R&D output. The latter is computed by dividing the quality-weighted patent count by the number of patents, $q_{ijct} = \frac{P_{ijct}^{qual.}}{P_{ijct}}$. To account for general quality shifts within the same industry as well as level differences across industries and countries, we then scale this measure by its 2-digit SIC industry, country- and year-specific mean $\bar{q}_{sct}$ and obtain $\tilde{q}_{ijct} = \frac{q_{ijct}}{\bar{q}_{sct}}$. We relate the logarithm of this relative measure to foreign patent box implementations in the following fixed effects regression:

$$\log\left(\tilde{q}_{ijct}\right) \quad = \quad \iota + \alpha \cdot BOX_{jt} + \boldsymbol{\beta X_{it}} + \boldsymbol{\gamma Z_{jt}} + \boldsymbol{\delta C_{ct}} + \boldsymbol{\phi_t} + \boldsymbol{\phi_i} + u_{it} \tag{4}$$

The specification of variables is the same as for equation (3).

Note that we are only able to compute the average quality of patents for firm-year observations where the firm successfully applied for a patent. In order to not distort our estimation by potentially confounding effects of the patenting decision of a firm, we restrict this regression to firms that generate patents before and after a patent box was implemented in a country where one of their foreign affiliates resides.[16]

[16]We also estimated equation 4 on the full sample and obtain virtually the same result.

Table 2: New Patents, 2000-2012

	Number of firms in sample	Share of firms with affiliate in patent box location		Avg. new dom. patents per year	Avg. new dom. patents per year (qual. wt.)
		Patent Haven	Nexus Patent Box		
AT	900	0.14	0.15	0.40	0.21
BG	66	0.03	0.00	0.21	0.08
CH	1,018	0.27	0.25	0.43	0.26
CZ	727	0.04	0.04	0.25	0.09
DE	10,207	0.11	0.12	0.38	0.20
DK	452	0.14	0.17	0.31	0.19
EE	43	0.00	0.00	0.23	0.10
FI	435	0.13	0.15	0.37	0.21
GB	3,256	0.16	0.19	0.30	0.19
GR	13	0.23	0.07	0.33	0.21
HR	18	0.11	0.05	0.13	0.07
IS	8	0.00	0.13	0.15	0.11
IT	3,056	0.06	0.06	0.30	0.16
LT	19	0.05	0.11	0.14	0.06
LV	42	0.00	0.00	0.21	0.06
NO	461	0.07	0.10	0.26	0.16
PL	422	0.06	0.07	0.29	0.14
RO	145	0.01	0.01	0.22	0.08
SE	737	0.20	0.21	0.33	0.21
SI	142	0.03	0.03	0.27	0.11
TR	392	0.02	0.03	0.23	0.07
Total	22,559	0.11	0.12	0.34	0.19

4 Data

4.1 Patent Data

The analysis is based on a rich panel dataset built by combining multiple data sources on patent data, firm information and patent box characteristics. Patent data is taken from the PATSTAT database operated by the European Patent Office (EPO). PATSTAT is a comprehensive data source covering patent data for over 80 countries in a harmonized way (Jacob, 2013). For the econometric analysis we count the number of granted patents per firm for each year.[17]

[17]Since it can take multiple years between application and approval of a patent, we account for this time lag between generating an innovation and acceptance of the patent application by using the date of first patenting

In our analysis we focus on domestically developed patents. In principal, the country of residence of the firm applying for a patent does not necessarily constitute the place of development of the patent. As is common in the literature, we identify whether or not a patent was developed at the location of the firm by using address information of the inventors (Guellec & de la Potterie, 2001). A patent is classified as domestic if the majority of its inventors reside in the same country as the applicant firm.[18] We remove outliers by trimming the sample at the 99 percentile of annual domestic patent output.

Table 2 displays descriptive statistics of the firm locations we include in our sample.[19] Research activity is particularly strong in Switzerland, Austria and Germany with average annual domestically developed patents per firm of 0.43, 0.40 and 0.38 respectively.

4.2 Ownership and Firm Data

We obtain PATSTAT patent data through Bureau van Dijk's Orbis database. This allows us to link patents of the applying firms to the comprehensive ownership information contained in the Bureau van Dijk's Amadeus database via common identifiers. The firm level databases by Bureau van Dijk are unique in two important ways. First, they provide information on the organizational structure of multinational firms around the globe. Second, they contain firm-level balance sheet data in an internationally comparable format. Both features are crucial for the analysis of cross-border spillovers through MNEs and have also been exploited to identify other types of international transmissions (e.g. Cravino & Levchenko, 2017).

Using the ownership information, we are able to identify the ultimate owner for each firm in the sample. We construct multinational groups by assigning firms with a common ultimate owner to the same group. This approach is complemented by checking whether the firm existed throughout the whole observation period to exclude tax-driven affiliate establishment in patent box countries. Finally, we combine the ownership information with data on mergers and acquisitions (M&A) from Bureau van Dijk's Zephyr database to capture ownership changes within the observation period. We exclude all groups where the firm structure changed with respect to the patent box locations displayed in Table 1. That is, all groups are excluded where one of the affiliates in a patent box location has been established, acquired or sold during our sample period. In line with Stiebale (2016), we further restrict our sample to industries where patenting is actually relevant. We include firms active in the manufacturing sector as well as several knowledge-intensive service sectors such as information technology, telecommunications, transport, R&D, or business-related services.[20] Table 2 provides infor-

application instead of the patent publication date.

[18] For those patents with no inventor information provided by PATSTAT, it is assumed that the patent was developed domestically. As a robustness check, it is also assumed that all patents without inventor information provided are non-domestic ones. The results still hold true implying that these patents are not systematically different from those with inventor information.

[19] An overview of the sample selection process is displayed in Table A.2 in the Appendix.

[20] This excludes financial services. We identify relevant sectors via 2-digit NACE Rev. 2 codes and include

mation on the geographical distribution of firm observations over the 22 locations that remain after excluding patent box locations.

Table 3: Summary Statistics

	Number of Observations	Mean	Standard Deviation	Min	Max
New patent appl.	260,103	0.342	0.867	0	7
New patent appl. (qual. adj.)	260,103	0.188	0.526	0	6.582
BOX_{Haven}	260,103	0.113	0.317	0	1
BOX_{Nexus}	260,103	0.080	0.270	0	1
Δt	250,551	1.782	6.376	0	31.4
Number of affiliates	260,103	11.655	43.357	1	1,094
Log Age	253,123	2.672	1.041	0	6.592
Log Total Assets	260,069	9.154	2.473	-8.151	17.342
Working Capital	260,069	-7.154	2,084.461	-769,074	344,886
Log Capital Intensity	251,390	-2.774	2.262	-24.089	10.901
Corporate income tax rate	260,103	32.003	6.964	10	52
User cost of R&D capital	260,103	0.345	0.023	0.115	0.364
Real interest rate	251,321	0.056	0.020	-0.014	0.265
R&D expenditures (% of GDP)	258,481	2.121	0.723	0.323	3.914
Log GDP p.c.	260,103	10.416	0.431	7.920	11.143
GDP Growth	260,103	1.443	2.682	-14.814	11.902

We also obtain balance sheet items as well as firm age from Amadeus. Working capital is computed by scaling the difference between current assets and current liabilities with total assets, while capital intensity is defined as the ratio of tangible fixed assets and sales.[21]

Macroeconomic control variables are obtained from the World Bank's World Development Indicators (WDI) and the OECD. Tax policy indicators are collected from the IBFD tax database. When computing the user cost of capital, we follow Bloom *et al.* (2002) and incorporate the input incentives, the applicable tax rate and the fixed depreciation rate into a measure for the user cost of a domestic R&D investment. In order to isolate the effect of tax policy on R&D activity, we calculate the user cost using a fixed interest rate of 5%.[22]

We restrict our sample to the period 2000-2012. Before 2000, information on balance sheets and shareholders in the Bureau van Dijk database is sparse and the Zephyr database is fragmentary[23] so there is no reliable information on M&A that would also identify the

firms with codes 10-32, 51-53, 58-63, 69-74 and 77-82.

[21] Missing entries for the necessary variables are replaced by annual industry (2-digit US SIC code) means.

[22] See Appendix A.3 for a detailed description of the calculation of user cost of capital.

[23] See Table 1 in Bollaert & Delanghe (2015).

Table 4: Treated vs. Non-treated Firms

Panel A: Distribution Across Industries (Share of firms in industry)

	Manufacturing	Transportation and Storage	Information & Communication	Professional, Scientific & Technical Activities	Administrative & Support Service Activities
Treated	0.8069	0.0021	0.0282	0.1394	0.0233
Non-treated	0.7371	0.0042	0.0440	0.1828	0.0319

Panel B: Means of Key Variables

	User cost of R&D Capital	CIT	Log GDP per capita	Total Assets (th. USD)	Age	No. of affiliates
Treated	0.35	32.23	10.43	173,582.76	27.46	66.39
Non-treated	0.340	30.49	10.32	122,265.82	22.13	3.28

vendor in such deals.[24] We stop our sample period in 2012 because from 2013 onward, several large European economies (including United Kingdom, Italy, Portugal) implemented domestic patent box regimes. This means that we cannot include these locations in our analysis of cross-border spillovers of patent boxes.[25] Furthermore, the process of granting patents usually takes several years, such that for more recent periods we do not yet observe the full amount of R&D output. Table 3 provides summary statistics for all variables used in the empirical analysis.

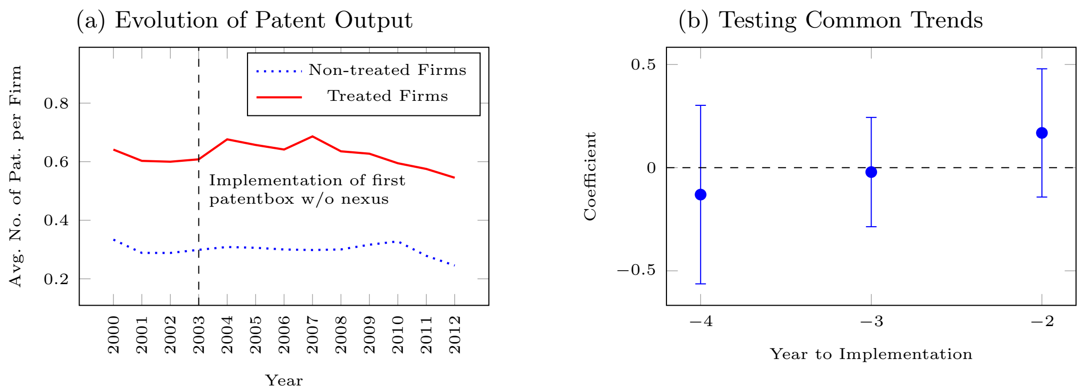
4.3 Identifying Assumptions

As mentioned above, for the cross-border effect of patent boxes to be identified, we require firms with affiliates in patent havens (treated) and those that do not have affiliates in these countries (non-treated) to be comparable. We begin by observing various characteristics of the two types of firms. In Table 4 we display the distribution across industries (NACE Rev. 2 divisions) of the two groups (Panel A) and state the within-group averages for key variables (Panel B). Treated and non-treated firms have a similar distribution across industries, with the majority of patenting firms in the manufacturing and services sectors. They are also similar with respect to location-specific variables such as the user cost of R&D capital, the statutory corporate income tax rate and GDP per capita. This implies that firms with affiliates in patent box countries are not clustered in certain locations and, therefore, our results are not

[24]The SDC Thomson Reuters database, which would be an alternative to Zephyr, contains the variable "seller". However, entries are missing in the vast majority of cases.

[25]In a robustness check, we extended the sample to 2014 but excluded firms located in countries with patent boxes after their implementation. The results remain highly significant with coefficients of similar size.

Figure 2: R&D Activity Over Time



driven by such a clustering. The two groups differ, however, with respect to size (measured in total assets), age and the number of affiliates within their corporate group. Firms with foreign affiliates in patent havens are larger, older and more often part of large multinational groups. This difference in levels is, however, not surprising as a large part of the non-treated firms operates domestically. We control for this by including the respective variables in our regression model.

R&D activity in treated and non-treated firms may still be subject to different time trends which are driven by unobservable factors. In Panel (a) of Figure 2 we plot the evolution of the average number of patents per firm for treated and non-treated firms in our sample over time to verify whether such factors are behind our result. We observe that for the years before the occurrence of the first patent haven (2003, Hungary), the trends of the two groups are very similar. After 2003, R&D activity slightly increases in firms with affiliates in patent havens relative to those without. We attribute this increase to the decrease in the user cost of capital for R&D investment induced by the profit shifting opportunities arising from the patent box implementation. More generally, there appears to be no substantial difference in the time trends of the two groups which allows us to base our subsequent analysis on a comparison between them.

The assumption of a common trend before the foreign patent box implementation can also be tested econometrically using an event-study design (e.g. Hoynes *et al.*, 2011; Kline, 2012; Chetty *et al.*, 2014). In this setting, the number of new patent applications of a firm is regressed on a set of dummies indicating periods before and after the implementation of the patent box in the country of residence of one of its foreign affiliates. We describe our event-study design in more detail in Appendix A.3 and further elaborate on the results below. For now, we are mainly interested in the dummies indicating pre-implementation periods. For our research design to be valid, the estimated coefficients for these dummies should not be significantly different from zero indicating that there exists no difference in the pre-implementation trend of patent output between treated and non-treated firms.[26] We plot the coefficients and the 95% confidence intervals in Panel (b) of Figure 2. The indicator for the year prior to the implementation is normalized to zero. None of the other pre-implementation dummies is significantly different from zero and we also cannot reject the hypothesis that they are jointly equal to zero (F-test statistic 0.63). From this result we infer that our econometric approach is valid and correctly identifies cross-border spillovers of patent boxes if they exist.

5 Results

5.1 R&D Quantity

Table 5 contains the main estimation results.[27] In columns (1) to (4) we present results with regard to patent havens. In column (1), the cross-border effect is captured by a dummy BOX_{Haven} that indicates a relevant patent box implementation in the residence country of a foreign affiliate of a firm. The foreign tax cut leads to a significant increase of domestic patenting activity by 67 log points. This translates into an rise of annual patent output by approximately 95% and points to a strong external effect of foreign tax incentives on domestic research activity. Evaluated at the sample average, the result implies that the patent box implementation in a foreign affiliate location increases domestic R&D activity from about one patent every three years to about one patent every one and a half years. Thus, our result suggests that a decline in the user cost of capital in one location of a multinational group also affects group members with no relevant tax policy change.

As discussed above, firm-level patent output is also driven by other macroeconomic factors and policies. R&D expenditures as a share of GDP increases patent output of firms. On the contrary, an increase in the financing cost measured by the real interest rate or a higher statutory corporate income tax rate are expected to induce a decline in innovative activity. Consistent with related studies (e.g. Bloom *et al.*, 2002; Wilson, 2009), our estimates suggest that an increase in the user cost of R&D capital leads to a decline in corporate R&D investment. The fact that the coefficient for the patent box dummy remains significant despite the inclusion of the user cost of R&D capital indicates that our estimates are not the result of the fiscal competition game described above.[28] The significantly positive coefficients of total assets and the firm age indicate that, consistent with previous findings, larger and also older firms conduct more R&D.

In column (2) of Table 5 we capture the treatment intensity. Instead of an implementation

[26]Note that this test is similar in spirit to a Granger (1969) causality test.

[27]We also ran all regressions without control variables and obtained significant estimates for the variables of interest which were similar in size to the results of the benchmark regression.

[28]We also ran regressions restricting the set of control variables to macro-economic factors first and then excluding all control variables (keeping year-fixed and firm-fixed effects in both cases). The resulting coefficient estimates were qualitatively similar albeit somewhat larger in magnitude.

Table 5: Benchmark

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	No. of new Patents		No. of new Patents (quality-weighted)		No. of new Patents		No. of new Patents (quality-weighted)	
BOX_{Haven}	0.670***		0.611***					
	(0.202)		(0.221)					
$BOX_{Haven} \times \Delta t$		0.023***		0.020**				
		(0.008)		(0.008)				
BOX_{Nexus}					0.002		-0.042	
					(0.032)		(0.034)	
$BOX_{Nexus} \times \Delta t$						-0.001		-0.002
						(0.001)		(0.002)
R&D Exp.	0.333***	0.334***	0.444***	0.445***	0.340***	0.340***	0.452***	0.450***
	(0.065)	(0.065)	(0.072)	(0.072)	(0.065)	(0.065)	(0.072)	(0.072)
Log GDP p.c.	-0.380*	-0.380*	0.890***	0.890***	-0.387*	-0.388*	0.885***	0.883***
	(0.223)	(0.223)	(0.234)	(0.234)	(0.224)	(0.223)	(0.235)	(0.235)
CIT	-0.004*	-0.004*	-0.007***	-0.007***	-0.004*	-0.004*	-0.006**	-0.007***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
GDP Growth	-0.000	-0.000	-0.015**	-0.015**	-0.000	-0.000	-0.014**	-0.014**
	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)
User Cost of R&D	-5.573***	-5.570***	-4.368***	-4.365***	-5.563***	-5.543***	-4.284***	-4.292***
	(0.555)	(0.555)	(0.588)	(0.588)	(0.557)	(0.556)	(0.589)	(0.589)
Real interest rate	-1.395**	-1.393**	-1.730***	-1.728***	-1.383**	-1.379**	-1.704***	-1.704***
	(0.545)	(0.545)	(0.563)	(0.563)	(0.545)	(0.544)	(0.562)	(0.563)
No. of affiliates	0.119***	0.119***	0.112***	0.112***	0.120***	0.120***	0.112***	0.112***
	(0.039)	(0.039)	(0.041)	(0.041)	(0.039)	(0.039)	(0.041)	(0.041)
Log Age	0.089***	0.089***	0.088***	0.088***	0.088***	0.088***	0.086***	0.086***
	(0.021)	(0.021)	(0.023)	(0.023)	(0.021)	(0.021)	(0.023)	(0.023)
Log Total Assets	0.035***	0.035***	0.023***	0.023***	0.035***	0.035***	0.024***	0.024***
	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)
Working Capital	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.017***	0.017***	0.016***	0.016***	0.017***	0.017***	0.016***	0.016***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
N	229,723	229,723	222,701	222,701	229,723	229,723	222,701	222,701
No. of firms	20,414	20,414	19,761	19,761	20,414	20,414	19,761	19,761
Pseudo LL	-115,431	-115,433	-67,719	-67,720	-115,442	-115,441	-67,722	-67,721

Estimation of a Poisson fixed effects model. The dependent variable is the (quality-weighted) number of new patents per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

dummy, we use the tax rate divergence between the location of the firm and the patent box country in the year of the patent box introduction. More specifically, we take the difference between the corporate income tax rate in the residence country of the firm and the applicable tax rate for patent profits in the relevant affiliate country after the introduction of the patent box and interact it with our implementation dummies BOX_{Haven} and BOX_{Nexus}. We then repeat regression (1) using our more sophisticated indicator. Again, the coefficient of interest is significantly positive. Our results suggest that a patent box that induces a tax difference of 1 percentage point between the residence country of the firm and the relevant affiliate country raises the number of patents by 2.3%. For instance, take the example of a firm residing in Germany that has an affiliate in Hungary. The patent box implementation in the affiliate location in 2003 implied a tax differential of 31.2%. Our estimates suggest that this increased research activity in the German firm by 71.76%.

In a second step, we use the quality-weighted patent count as a dependent variable to control for the fact that patents may vary strongly with regard to their quality, usefulness and applicability (see Hall *et al.*, 2010). Columns (3) and (4) of Table 5 present the results from repeating the previous regressions with this alternative dependent variable. Throughout the specifications, the coefficients of the patent box implementation dummy as well as the one for the more sophisticated measure of the patent-box-induced tax difference remain significantly positive. Again, including location-, firm-, and group-specific controls suggests that our results are not driven by macroeconomic factors or endogenous firm selection. We note that the coefficients for the variables of interest are slightly smaller than in the regression with a simple patent count. This may reflect that there exist cross-border externalities of patent boxes not only with respect to the quantity of patent output but also with respect to their quality. Our theoretical analysis suggests that external effects on quality are negative and thus potentially mitigate the positive quantity effect if this is measured with quality weights. We turn to this additional effect in more detail below.

Finally, we are also interested in the cross-border effect of nexus patent boxes on R&D activity. In columns (5) to (8) of Table 5 we present results of a Poisson fixed effects estimation that relates the simple and quality-weighted patent count to a dummy BOX_{Nexus} that switches to one when the residence country of one of the foreign affiliates of the firm implements a patent box with nexus requirement.

Column (5) reports the results with regard to an implementation dummy which also contains the full set of controls. The coefficient of interest turns out positive, which potentially hints to some remaining profit shifting opportunities in nexus patent boxes. When relating the patent count to the tax difference implied by the patent box implementation rather than the simple reform dummy, the sign of the estimated coefficient becomes negative. However, in both specifications the coefficient is small in magnitude and insignificant. Similar results are obtained when accounting for patent quality in columns (7) and (8).[29] We investigate this effect in more detail below. In general, we cannot identify positive spillovers for nexus patent boxes.[30] This is consistent with the notion that patent boxes only reduce the user cost of R&D capital and thus raise R&D activity in other countries if they do not inhibit profit shifting via the relocation of intangibles.

5.2 R&D Quality

In Table 6, we present estimates of the cross-border spillover effect of a patent box implementation on the average quality of patents. Column (1) contains the regression result relying on a dummy indicating that one of the affiliate countries of a firm turned into a patent haven and the set of control variables and fixed effects described above. The negative coefficient suggests that the patent box implementation leads to a reduction in relative patent quality. In column (1) this regression is repeated using the resulting tax difference from the patent box as the variable of interest. Again, the estimated coefficient is negative and significant. In columns (3) and (4), the regressions are repeated with a dummy that takes value one if firms have an affiliate residing in a country with a nexus patent box implemented or the corresponding tax difference, respectively. Having an affiliate in such a country reduces the average quality of domestic patents, albeit to a lesser extent. This result is also obtained when accounting for the actual tax difference between the location of the patenting firm and its patent box affiliate.

The negative cross-border effect of patent havens possibly reflects a decrease in the average profitability of granted patents, which is consistent with our theoretical findings above. Note that even though the direction of the effect does not depend on the nexus requirement of the patent box, our analysis suggests that the underlying mechanism differs between the two types of patent boxes. This may also explain the difference in the magnitude of the coefficients. The estimated effect on average patent quality is about five and a half times larger for a patent haven than for a nexus patent box. We therefore conclude that the effect on the intensive margin, which is driven by foreign patent havens that allow firms to conduct more but also less profitable R&D, is more pronounced in practice. In comparison to this, the effect on the extensive margin, which results from nexus patent boxes that lure away R&D projects with high profitability, is much smaller.

[29] We note that the observed effect for the quality-weighted patent count may also be driven by the negative impact of foreign patent boxes on domestic patent quality that is suggested by our theoretical framework.

[30] In untabulated tests we also included both implementation dummies BOX_{Haven} and BOX_{Nexus} as well as there interaction into one regression. We found a significantly positive coefficient for BOX_{Haven} that is similar to the results in Table 5 while the coefficients for BOX_{Nexus} and the interaction are insignificant and small in magnitude.

Table 6: Patent Quality

	Patent Quality			
	(1)	(2)	(3)	(4)
BOX_{Haven}	-0.269**			
	(0.108)			
$BOX_{Haven} \times \Delta t$		-0.009**		
		(0.004)		
BOX_{Nexus}			-0.048***	
			(0.015)	
$BOX_{Nexus} \times \Delta t$				-0.002***
				(0.001)
R&D exp.	0.111***	0.110***	0.129***	0.127***
	(0.034)	(0.034)	(0.037)	(0.037)
Log GDP p.c.	-0.205**	-0.205**	-0.190*	-0.191*
	(0.101)	(0.101)	(0.114)	(0.114)
CIT	0.001	0.001	0.001	0.000
	(0.002)	(0.002)	(0.002)	(0.002)
GDP Growth	0.001	0.001	-0.000	-0.000
	(0.003)	(0.003)	(0.003)	(0.003)
User Cost of R&D	-0.913***	-0.914***	0.480	0.467
	(0.316)	(0.316)	(0.401)	(0.401)
Real interest rate	-0.621*	-0.620*	-0.464	-0.467
	(0.320)	(0.320)	(0.352)	(0.352)
Log no. of affiliates	-0.034	-0.034	-0.041	-0.041
	(0.022)	(0.022)	(0.025)	(0.025)
Log Age	-0.006	-0.006	-0.011	-0.010
	(0.013)	(0.013)	(0.015)	(0.015)
Log Total Assets	-0.022***	-0.022***	-0.023***	-0.024***
	(0.004)	(0.004)	(0.004)	(0.004)
Working Capital	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.001	0.001	0.001	0.001
	(0.003)	(0.003)	(0.004)	(0.004)
N	50,766	47,225	39,613	36,136
No. of firms	21,513	19,857	15,772	14,117
R^2	0.014	0.017	0.014	0.018

Estimation of an OLS fixed effects model. The dependent variable is the logarithm of average patent quality per year and firm for patents for which the majority of inventors does not reside outside the country of residence of the firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

5.3 Additional Robustness Checks

The validity of our results is reassured when exposing them to various robustness checks. We discuss the most important tests here and relegate the corresponding results to the Appendix.

First, we conduct several sample checks. Multinational groups often operate multiple affiliates within a country. The spillover effect resulting from the introduction of a patent box regime in a foreign affiliate can thus affect affiliates within a country differently. Hence, in Table A.6, we consolidate all group affiliates in the same country and re-estimate the main specification. Reassuringly, we find results which are very similar to those in Table 5. Hence, we can preclude that the spillover effect is limited to single affiliates only. Another concern may be that the firms in our sample are not sufficiently comparable since we include both domestic and multinational corporations. We verify that this is not the case by reestimating our benchmark results with a sample restricted to MNEs. Results are presented in Table A.7. Reassuringly, the coefficient estimates are very similar to those in our benchmark regression. Our results are thus not driven by incorrectly comparing multinational firms to domestic groups or stand-alone entities.

Second, we check whether the direction of our estimated effect is driven by the model choice by reestimating equation (3) in a linear model which relates the logarithm of the patent count to the specification described above. This approach excludes all firm-year observations in which no patent was granted. In an additional estimation we avoid this problem by replacing the resulting missing values by zero. The results for this exercise are displayed in Table A.8 and reveal that qualitatively similar effects are detected in a linear fixed effects regression model.

Untabulated robustness checks include re-estimations of the benchmark model including industry-specific and location-specific time trends as well as separate time trends for MNEs and domestic firms. We obtain virtually the same results in all specifications.

Third, the differences in average assets, age and group size between treated and untreated firms (see Table 4) could be indicators for endogenous sorting causing a self-selection bias (Wooldridge, 2010). For example, a member of a large group is more likely to be assigned to the treatment group simply because of having more foreign affiliates and, thus, having a higher probability that one of these foreign affiliates gets access to a patent box. However, if affiliates of large groups exhibit a different evolution of patent output during the sample period, comparability of treatment and control group is limited. To verify that this precludes any selection bias, we re-estimate our benchmark results by applying matching approaches to account for structural differences between treatment and control group. This allows us to compare treated and untreated firms with similar characteristics. We employ Propensity Score Matching (PSM) as well as Coarsened Exact Matching (CEM). Matching is conducted on the full set of control variables with values in 2000 to capture structural differences of firms at the beginning of our sample period as well as variable values for current differences in each year. With matching on variable values in 2000 we establish initially similar compositions of treatment and control group but allow for heterogeneous developments of firms within groups. When matching on current observables, we balance the sample in each year to capture time-varying differences in firm development. For PSM, the propensity score for being treated is calculated using a Probit regression with treatment status as dependent variable and firm characteristics as controls[31]. The propensity score is used to find for each treated firm sufficiently similar firms from the untreated group to conduct a Difference-in-Difference analysis in patent output. However, despite the popularity of PSM, its underlying Probit regression is likely to be prone to outliers resulting in bias and inefficiency (King & Nielsen, 2015). An alternative that avoids these problems is CEM which, unlike PSM, is a fully non-parametrically procedure. The underlying idea is to coarsen the values of each variable into groups and then identify similar firms according to variable values assigned to similar groups. Based on these group assignments, a weight for each firm is calculated. The more variable realizations of a treated and an untreated firm get assigned to the same group, the higher the resulting weight. We use the resulting weights and re-estimate equation (3). Reassuringly, the estimated average treatment effect on the treated (ATT) across different matching specifications as reported in Table A.10 is similar to our benchmark regression results in Table 5. Therefore, we rule out endogenous sorting of firms into the treatment group.

5.4 Extensions

In this section, we consider several extensions to our benchmark analysis. We examine heterogeneities across industry sectors, we observe the evolution of the cross-border effect of patent boxes over time using an event-study design and we compute the elasticity of R&D output to various measures of the effective tax burden within company groups. The first two analyses aim at further verifying the plausibility of our results while the latter exercise highlights more general aspects of our results. Finally, we complement our analysis of patent output using additional information on R&D expenditures of German firms to check whether the impact of the foreign, output-related tax incentives we study is also reflected in the structure of domestic R&D spending.

Industry Heterogeneity

With regard to industry heterogeneity, industries with shorter development phases and a lower level of input costs are likely to react earlier and stronger as they can more easily adjust their patent output to external incentives. Firms that are commonly associated with such characteristics are those active in the Information and Communications Technology (ICT) sector. In contrast, the development processes of manufacturing firms, in particular those

[31] For a more detailed description, see Table A.9.

active in the pharmaceutical and chemical sector, are usually slow and costly. Their response to foreign tax incentives should thus be less pronounced.

To check whether the data reflects such a pattern, we repeat the quantity regressions described above for two sub-samples of firms. First, we only include ICT firms[32] and then restrict the sample to manufacturing firms[33] other than ICT. Results are presented in Table A.3 in the Appendix. Columns (1) and (2) contain the results for ICT firms. Consistent with the notion that R&D output of these firms responds more quickly, the estimated coefficient for BOX_{Haven} is substantially higher than that in our benchmark regression. All other factors equal, this implies that for ICT firms, taxation constitutes a more important cost factor and a decrease in the tax burden on R&D investment constitutes a greater incentive to raise their R&D activity. In contrast, the response of other manufacturing firms is weaker. The estimated coefficients in columns (3) and (4) are significantly positive but of lower magnitude than the ones in our benchmark results. Consistent with prior literature, these firms have longer R&D processes and thus do not adjust their research output to policy incentives as quickly. Finally, we do not find cross-border effects for nexus patent boxes.

Dynamics of the Spillovers

Next, we apply an event-study design to the analysis of patent havens which is described in detail in Appendix A.3. The general idea of the event study is to regress the number of patents on individual dummies indicating periods before and after the implementation of a foreign patent haven. In this more flexible setup, we can explore the evolution of the cross-border effect over time. In particular, one may expect a lagged response because an increase in patent output requires prior research efforts.

Figure 3: Event-study Design

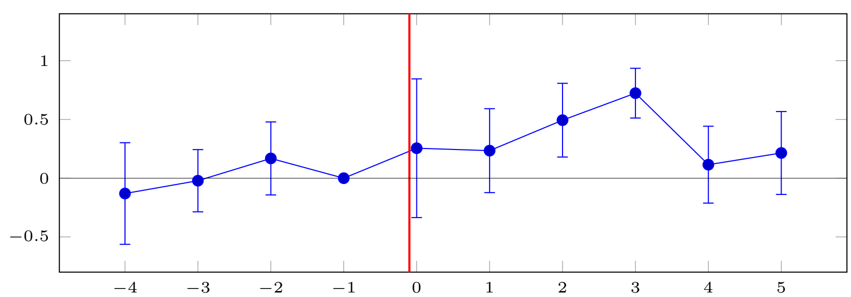


Figure 3 plots the results of the event-study analysis. The effect is normalized to zero in the year before the patent box implementation and the coefficients have to be interpreted as the effect of the foreign patent box on patent output relative to the year prior to the reform. As

[32]NACE Rev. 2 codes 5821, 5829, 6010, 6020, 6110, 6120, 6130, 6190, 6201, 6202, 6203, 6209, 6311, 6312, 6391, 6399, 2611, 2612, 2620, 2630, 2640, 2651, 2680, 2731, 2732.

[33]NACE Rev. 2 codes 10 to 33.

highlighted above, we find no significant impact of the patent box prior to its implementation which is reassuring with regard to the causality of our findings. We also observe that the effect does not materialize immediately. Rather, a significant response is obtained starting in the second year after the patent box implementation. This suggests that some time is needed for R&D processes to adjust. In year four after the implementation, the coefficient decreases and becomes insignificant. Even though this might imply that in the long run the cross-border effect of the patent box diminishes, we refrain from interpreting the coefficients in this way because long-run estimates of the firm response are more precisely determined using the non-linear count model in our benchmark analysis. Generally, obtaining reliable long-run estimates in an event study would require a longer observation period and, as in Kline (2012), the coefficients for the event window ends may be biased as they give unequal weights to patent boxes implemented early or late in our observation period since the sample is unbalanced in event time.

The Effective Tax Burden of R&D

Finally, we turn to implications of our findings for the measurement of the tax burden on corporate R&D investment in the presence of cross-border spillovers of patent boxes. An important issue raised by the literature on tax havens and investment of MNEs (e.g. Hong & Smart, 2010) is that the domestic tax rate of a jurisdiction may not be very informative with respect to the tax environment faced by such firms for investing in this jurisdiction. Since internationally operating firms are able to shift part of their profit from one location to another, their effective tax burden in one location is likely to depend on the applicable tax rates in the whole group. With sufficiently low costs of profit shifting, such as in the case of patent rights, it is the location with the lowest tax rate in the group that determines the effective tax burden of its members.

We test this notion by replacing the main variable of interest BOX in equation (3) by several measures for the effective tax rate for profits faced by a firm. We are interested in how R&D activity reacts to each of these measures. They include the statutory corporate income tax rate and the minimum tax rate on patent profits within the whole group. For the latter, we again distinguish between nexus patent boxes and patent havens. Effectively, we extend our analysis beyond the particular incidence of a foreign patent box implementation and exploit the full variance of tax rates on patent profits in a multinational group to identify cross-border effects on patent output.

Following Hong & Smart (2010) and Slemrod & Wilson (2009), the statutory tax rate should be relevant only for firms without foreign affiliates. The minimum tax rate within a group should be more informative for the whole sample but only if we take into account tax rate reductions of patent boxes without nexus requirement. Table 7 displays the results of this exercise. In column (1), the variable of interest is the statutory corporate income tax

Table 7: R&D Activity and Corporate Taxation

	No. of new Patents			
	(1)	(2)	(3)	(4)
	Full Sample	Domestic Firms	Full Sample	Full Sample
CIT	-0.004	-0.007**		
	(0.002)	(0.003)		
Minimum Tax Rate (No Nexus)			-0.004**	
			(0.002)	
Minimum Tax Rate (Nexus)				-0.003
				(0.002)
N	229,723	175,163	229,723	229,723
No. of firms	20,414	15,701	20,414	20,414
Pseudo LL	-115,442	-77,860	-115,439	-115,442

Estimation of a Poisson fixed effects model. The dependent variable is the number of new patents per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%. Controls are reported in Table A.4 in the Appendix.

rate. The respective coefficient is negative with a tax cut by one percentage point causing an increase in R&D activity by about 0.4%. This result is, however, insignificant, implying that the statutory tax rate is not very informative with respect to the tax environment of a firm in our sample. In column (2), we restrict the sample to firms without foreign affiliates. The coefficient for the statutory corporate income tax rate is now larger and significantly negative. Our results suggest that for domestically operating firms a one percentage point decrease in the corporate income tax rate would raise R&D activity by about 0.7%. Next, we use the minimum tax rate on patent profits within the group of affiliates of a firm as a measure of the tax burden in column (3). In doing so, we take into account tax reductions resulting from the implementation of patent havens. In contrast to the regression in column (1), the coefficient for this adjusted tax rate measure is significantly negative and implies that an effective tax rate decrease by one percentage point leads to an increase of patent output by 0.4%.

Thus, our results indicate that the effective tax burden of a firm with respect to R&D investment is better described by also taking into account tax rate changes in the whole group. The statutory corporate income tax rate remains, however, informative for firms that operate in one country only. Consistent with our expectation that spillovers only occur from patent havens that allow for profit shifting, we do not find a significant effect of the minimum group tax rate when we account for tax cuts induced by foreign nexus patent boxes. The corresponding coefficient in column (4) is negative but insignificant.

R&D Expenditures

Our analysis focuses on R&D output measured by patent applications as this captures the firm response that directly corresponds to the tax incentive we study. In the following extension, we investigate how and to what extent the output response transmits to the R&D input choice of a firm. Although firm innovation is not necessarily proportional to its R&D expenditures (Hausman *et al.*, 1984), the structure of the latter should still reflect the underlying tax incentives for R&D output.

Detailed information on R&D inputs is scarce. Corporations are usually not required to report them and are generally reluctant to publish related information because of the strategic information contained in these figures. In the following analysis we use confidential survey data collected from German corporations.[34] The data is collected on a biannual basis and feeds into the Eurostat database on corporate R&D. Since the identifier used by the Stifterverband is identical to the one in the Bureau van Dijk databases, we can directly link our ownership and tax policy information as well as the balance sheet items used as controls to the R&D expenditures data of the Stifterverband. In total, we observe 7,682 firms from 2001 to 2013 on a biannual basis (30,134 firm-year observations) for which we also have information on the relevant control variables.

The empirical analysis follows specification (3) but replaces the patent count with several measures of R&D expenditures.[35] We focus on the implementation of patent havens for which we observe a significantly positive response of patent output.[36] Results are presented in Table A.5 in the Appendix. In column (1) we relate internal R&D expenditures to the indicator of a foreign patent haven implementation. The effect is small and insignificant which suggests that the increase in corporate innovation triggered by the foreign patent box is not immediately reflected in an increase of internal R&D expenditures. However, we find a significant impact of the patent box on the *structure* of internal R&D spending. In column (2) and (3), we separate it into expenses for applied and experimental research according to the Frascati Manual (OECD, 2015).[37] Applied R&D aims at generating new products and processes while experimental research further develops existing innovations. Expenditures of German firms for the latter increase with the implementation of a foreign patent box. This may reflect that the

[34] We use the R&D survey of the Wissenschaftsstatistik of the Stifterverband.

[35] Since the analysis is restricted to firms residing in Germany, we capture macro-economic shifts by including year-fixed effects as in the benchmark specification and drop macro-economic control variables due to collinearity.

[36] We also analyzed the response to patent box implementations with nexus requirement (unreported) and found no significant effect on R&D inputs.

[37] A third item is basic research, which is, however, usually unrelated to business goals and thus of minor importance for the firm. In an unreported estimation we found no effect of foreign patent box regimes on this type of expenditures.

tax cut on patent profits in one of their affiliate location incentivizes firms to spend more on the development of existing ideas in order to generate patents that can later be transferred to the low-tax affiliate. Doing so avoids the substantial fixed costs of starting new R&D projects but still allows firms to benefit from the profit shifting opportunity. The negative impact on applied research expenses is probably a result of firms concentrating resources in experimental R&D activity. These results are also consistent with our finding that R&D quality decreases in response to the patent box implementation since the innovative character of experimental R&D activity, to which expenditures are shifted, is generally lower than that of applied R&D activity.

Finally, we estimate a significantly negative coefficient for the foreign patent box indicator when we relate it to external contract R&D outside the group. In contrast to internal R&D activity, contract research is easily shifted by assigning the affiliate in the patent box location as the new purchaser of these services.[38] The result thus probably reflects that firms shift those R&D activities abroad which are only loosely attached via contract arrangements. In contrast, internal R&D expenditures are restructured in adjustment to the foreign tax incentive while not altering their overall level.

6 Conclusion

In this paper, we combine information on firm ownership, research activity and output-related R&D tax incentives to identify cross-border spillover effects of tax policy within multinational groups. Our results indicate that within multinational companies, the patent box implementation in one location also affects R&D output at other locations of the group. It increases the research activity there by 2.3% per percentage point of the induced tax rate differential. On average, this raises the patent output from about one patent every three years to about one patent every one and a half years. Consistent with our theoretical analysis, we find this effect only for patent boxes *without* nexus requirement (patent havens). In contrast, patent boxes *with* nexus requirement effectively preclude tax benefits from the transfer of intangibles and, thus, do not lower the effective tax burden on R&D investment across borders. Furthermore, we show that, in line with the predictions of a theoretical model, cross-border spillovers of patent boxes on patent quality are negative.

These results have several important implications. First, they provide empirical evidence with regard to the theoretical analyses by Desai *et al.* (2006) and Hong & Smart (2010), who argue that the presence of low-tax countries reduces the user cost of capital for investment in high-tax countries. It remains questionable whether tax havens are beneficial from an overall welfare perspective (see Slemrod & Wilson, 2009), but our analysis shows that the

[38] Since the measure refers to contract R&D outside of the MNE, exit taxes and CFC rules are also unlikely to apply in this case.

proposed mechanism is a relevant phenomenon for investments in intangible assets which are particularly mobile with regard to the allocation of related profits.

Second, these findings inform the ongoing debate on patent boxes. Some countries have argued that patent boxes are not effective in fostering domestic research activity but merely constitute an instrument for harmful tax competition. Indeed, existing empirical studies have not yet robustly identified a direct effect of patent boxes on domestic innovation. However, our results suggest that an indirect cross-border effect exists. If patent box regimes include non-domestically developed patents, the implicit tax reduction for multinational companies increases corporate R&D activity in other countries. An assessment of the overall welfare impact is precluded by the fact that we do not observe foregone revenue in the location of the domestic firm. Nevertheless, the results presented above suggest that when restricting profit shifting opportunities to foreign patent havens, governments must weigh the expected increase in domestic tax revenue against the negative impact on domestic research activity. Somewhat surprisingly, those patent boxes that provide the best opportunity for profit shifting are actually the regimes that have the strongest positive effect on research activity in non-patent box countries.

Results from our theoretical analysis suggest that there are two consecutive firm responses to the creation of a foreign patent haven. Companies first raise R&D output and then locate the resulting patent rights to the patent box location. In our empirical analysis we have verified the first step which is relevant for the cross-border implications of patent boxes on real R&D activity. More generally, we are interested in the impact of patent boxes on corporate innovation rather than on the resulting profit allocation. As it is the case for many corporate investment decisions, the former effect depends on the *expected* tax rate on future profits. Thus, the change of *prospective* taxation induced by the patent box, which we capture in our empirical specification, is decisive.

Even though, we do not identify the second step, we note that recent findings by Ciaramella (2017) and Gaessler *et al.* (2017) on patent relocation and the implementation of patent boxes, however, strongly point to the relevance of this effect. Furthermore, we note that empirical findings of previous studies suggest that profit shifting via the transfer of patent rights is a very relevant phenomenon (see Dischinger & Riedel, 2011; Karkinsky & Riedel, 2012). In fact, a recent empirical analysis by Koethenbuerger *et al.* (2016) on the effect of patent boxes on cross-border profit shifting suggests that the introduction of these regimes leads to substantial transfer of profits to the affiliates that are located in the implementing countries.[39] Consistent with our analysis, this effect is confined to patent boxes without sufficient nexus requirements.

[39] On the reverse effect, Chen *et al.* (2016) show that patent boxes reduce outward profit shifting in the countries where they are implemented.

Appendix

A.3 Patent Boxes and Average Patent Quality

The average profits are given by

$$\Pi = \int_{\tilde{\pi}^*}^{\tilde{\pi}} \pi_s f(\pi_s)\, d\pi_s.$$

The change in Π with respect to the tax differential is given by

$$d\Pi = -\left((1-\alpha) \frac{(c_p - c_h)\, \tilde{\pi} f(\tilde{\pi})}{((1-\alpha)\, \Delta t)^2} + \alpha \frac{c_h \tilde{\pi}^* f(\tilde{\pi}^*)}{(1 - t_h + \alpha \Delta t)^2} \right) d\Delta t < 0.$$

A.3 Composite Patent Quality Indicator

Patent quality is a latent variable which is not directly observable in the data. To approximate it, we follow the approach proposed by Lanjouw & Schankerman (2004) and employ a multiple-indicator model with one unobserved common factor. We use three different indicators, namely forward citations, patent family size and number of patent classifications codes (IPC classes). Therefore, the underlying equations for the multiple-indicator model are

$$y_{k,s} = \lambda_k v_s + \boldsymbol{\beta X} + e_{k,s},\ k \in \{1,2,3\}$$

where $y_{k,s}$ is the value of quality indicator k for patent s, v_s indicates the common factor, λ_k represents the factor loading, $\boldsymbol{X}$ contains common controls and $e_{k,s} \sim N(0,\sigma^2)$ is the idiosyncratic component with $Cov(e_{k,s}, e_{k,r}) = 0,\ s \neq r$. Since the term $\lambda_k v_s$ is latent, we estimate the reduced form of the equations:

$$y_{k,s} = \boldsymbol{\beta X} + u_{k,s},\ k \in \{1,2,3\}$$

where $u_{k,s} = \lambda_k v_s + e_{k,s}$ combines a common component $\lambda_k v_s$ and an idiosyncratic component $e_{k,s}$. We estimate these equations using 3SLS where $\boldsymbol{X}$ contains the year of application and the main technology class of the patent. To gather λ_k and v_s, we conduct a factor analysis using maximum likelihood to decompose $u_{k,s}$. The estimated factor loadings are presented in Table A.1.

Table A.1: Factor loadings

Indicator	Factor loading
Forward citations	0.6201
Patent family size	0.3593
Patent classification codes	0.1229

Factor analysis of the residuals from regressing each indicator on year and industry class dummies. Factor loadings represent both weighting of the indicator and correlation between indicator and patent quality.

We use the estimated factor loadings to calculate the composite quality indicator for each patent. The composite quality indicator is a relative measure to determine the quality of patents and is normally distributed with mean zero. To construct the quality-weighted annual patent count, we transform the distribution by adding the value of the patent with lowest patent quality so that all composite quality indicators turn positive. After this transformation the composite quality indicator for each patent has a positive value and can be used as weight for summing up patent output. The implied relative ordering of the quality of patents is unaffected by this transformation.

A.3 User Cost of R&D Investment

The computation of the user cost follows the derivation of Bloom *et al.* (2002) who extend its standard expression as presented by Hall & Jorgenson (1967) to R&D investment. The user cost is defined as the pre-tax financial return ρ for a marginal R&D investment project (i.e. a project with zero economic rent). The economic rent of an R&D project is given by

$$\begin{aligned} R &= (1+i)\, dV_t = dD_t + dV_{t+1} \\ &= \frac{(\rho+\delta)\left(1-\tau^{CIT}\right) + (1-\delta)\, A}{1+r} - (1-A) \end{aligned}$$

where dV_t is the change in the market value of the firm and dD_t is the change in dividends paid out by the firm that results from the investment. i denotes the nominal and r the real market interest rate and δ is the economic rate of depreciation. A is the net present value of allowances. Following Thomson (2013) and Warda (2002), we assume the R&D investment to consist of an investment in labor (60%), machinery and equipment (5%), buildings (5%) and other current expenditures (30%). A accounts for additional deductions, tax credits and accelerated depreciation. To obtain the user cost, we set $R = 0$ and solve for ρ. This yields

$$\rho = \frac{1-\left(A^D + A^C\right)}{1-\tau^{CIT}}\,(r+\delta) \tag{A.1}$$

We compute ρ_{ct} for every country and year and follow Bloom *et al.* (2002) in setting $\delta = 0.3$ and $r = 0.05$. Tax policy variables are obtained from the IBFD database.

A.3 Sample Selection

Table A.2: Sample Selection

	Number of Firms in the Sample
Firms in patenting sectors that conduct R&D with data for 2000-2012	38,906
Excluding firms located in patent box countries	30,923
Excluding firms with a change in the firm structure with respect to patent box locations	26,393
Trimming at the 99% quantile of the patent count	26,314
Excluding firms with no patent application in the observation period	22,559

This table displays the sample selection. Patenting sectors are defined by 2-digit NACE Rev. 2 codes 10-32, 51-53, 58-63, 69-74 and 77-82. Firms that conduct R&D are defined as firms included in the PATSTAT database that have successfully filed a patent application at any point in time.

A.3 Event-study design

The event-study design follows the standard setup (e.g. Hoynes *et al.*, 2011; Kline, 2012; Chetty *et al.*, 2014) and is specified as:

$$P_{ijct} = \alpha_{-4} \sum_{n=4}^{t-2000} b_{j,t+n} + \sum_{n=-3}^{-2} \alpha_n b_{j,t-n} + \sum_{n=0}^{4} \alpha_n b_{j,t-n} + \alpha_5 \sum_{n=5}^{2012-t} b_{j,t-n} \\ + \boldsymbol{\beta X_{it}} + \boldsymbol{\gamma Z_{jt}} + \boldsymbol{\delta C_{ct}} + \boldsymbol{\phi_t} + \boldsymbol{\phi_i} + u_{it}. \quad \text{(A.2)}$$

P_{ijct} is the number of newly granted patent applications P_{ijct} of firm i which is member of multinational group j and is located in country c in period t, and $b_{j,t}$ is a dummy that indicates whether in year t group j has an affiliate in a country where a patent box without nexus requirement is implemented and zero otherwise. Within the first and last year in our sample, 2000 and 2012, we define an event window of 10 years, that is, we observe 4 years before and 5 years after the implementation of the patent box as well as the implementation year itself. In each year, we thus compare the treated firms to those that do not have a foreign patent box affiliate. Following Kline (2012) we adjust the end points of the event window to indicate whether a foreign patent box has been implemented 4 or more years before (upper window limit) and 5 or more years after a given year (lower window limit) in order to mitigate collinearity with the year-fixed effects. To avoid perfect collinearity among the patent box indicators, the regressor in the year before the implementation is dropped and thereby normalized to zero. As a consequence, the remaining coefficients α_t are interpreted as the effect of the patent box implementation on P_{ijct} relative to the pre-reform year. The regression is complemented by a set of control variables which are identical to the main specification (3) as well as a set of firm-fixed and year-fixed effects.

A.3 Additional Tables and Figures

Figure 4: Graphical Illustration of the Conceptual Framework

This figure illustrates the concept of this paper. The focus of the analysis is R&D activity of firm 1, located in country A with an affiliate in country B. We investigate the response of R&D activity of firm 1 to the patent box implementation in country B. Empirically, this is done by comparing firm 1 to another firm 2 which may have a a foreign affiliate in a country C but is not linked via an affiliate to the patent box country B.

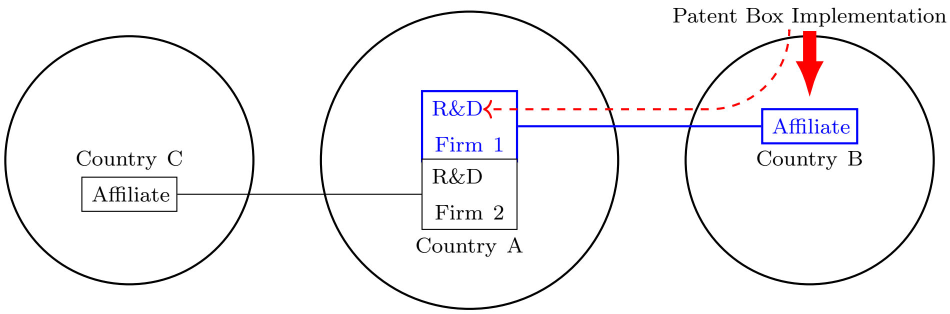


Table A.3: Heterogeneity Across Industries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ICT		Manufacturing		ICT		Manufacturing	
BOX_{Haven}	0.924**		0.575**					
	(0.408)		(0.247)					
$BOX_{Haven} \times \Delta t$		0.028*		0.020**				
		(0.016)		(0.010)				
BOX_{Nexus}					-0.187		-0.026	
					(0.115)		(0.036)	
$BOX_{Nexus} \times \Delta t$						-0.008		-0.002
						(0.005)		(0.002)
R&D Exp.	0.408*	0.415*	0.365***	0.367***	0.448**	0.437**	0.373***	0.372***
	(0.220)	(0.220)	(0.077)	(0.077)	(0.221)	(0.220)	(0.077)	(0.077)
Log GDP p.c.	-0.986	-0.997	-0.590**	-0.590**	-1.039	-1.040	-0.593**	-0.596**
	(0.960)	(0.961)	(0.245)	(0.245)	(0.954)	(0.956)	(0.246)	(0.245)
CIT	-0.000	0.000	-0.003	-0.003	0.001	0.000	-0.003	-0.003
	(0.008)	(0.008)	(0.003)	(0.003)	(0.008)	(0.008)	(0.003)	(0.003)
GDP Growth	0.004	0.005	0.002	0.002	0.007	0.007	0.002	0.002
	(0.019)	(0.019)	(0.007)	(0.007)	(0.019)	(0.019)	(0.007)	(0.007)
User Cost of R&D	-3.912*	-3.890*	-1.221*	-1.220*	-3.824*	-3.829*	-1.201*	-1.198*
	(2.014)	(2.014)	(0.666)	(0.666)	(2.009)	(2.011)	(0.666)	(0.666)
Real interest rate	-3.912*	-3.890*	-1.221*	-1.220*	-3.824*	-3.829*	-1.201*	-1.198*
	(2.014)	(2.014)	(0.666)	(0.666)	(2.009)	(2.011)	(0.666)	(0.666)
No. of affiliates	0.239*	0.240*	0.104**	0.104**	0.244*	0.244*	0.105**	0.105**
	(0.141)	(0.141)	(0.046)	(0.046)	(0.141)	(0.141)	(0.046)	(0.046)
Log Age	-0.025	-0.026	0.108***	0.108***	-0.036	-0.035	0.107***	0.107***
	(0.067)	(0.067)	(0.026)	(0.026)	(0.066)	(0.066)	(0.026)	(0.026)
Log Total Assets	0.045***	0.045***	0.035***	0.035***	0.050***	0.050***	0.036***	0.036***
	(0.017)	(0.017)	(0.007)	(0.007)	(0.017)	(0.017)	(0.007)	(0.007)
Working Capital	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.028**	0.028**	0.013**	0.013**	0.028**	0.028**	0.013**	0.013**
	(0.013)	(0.013)	(0.007)	(0.007)	(0.013)	(0.013)	(0.007)	(0.007)
N	22,243	22,243	162,224	162,224	22,243	22,243	162,224	162,224
No. of firms	2,012	2,012	13,937	13,937	2,012	2,012	13,937	13,937
Pseudo LL	-10,856	-10,857	-82,597	-82,598	-10,855	-10,856	-82,602	-82,600

Estimation of a Poisson fixed effects model. The dependent variable is the number of new patents per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. Columns (1), (2), (5) and (6) present estimations on the sample of ICT firms, columns (3), (4), (7) and (8) refer to results on the sample of manufacturing firms other than ICT. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

Table A.4: R&D Activity and Corporate Taxation: Controls

	No. of new Patents			
	(1)	(2)	(3)	(4)
	Full Sample	Domestic Firms	Full Sample	Full Sample
R&D exp.	0.340***	0.319***	0.347***	0.352***
	(0.065)	(0.086)	(0.063)	(0.063)
Log GDP p.c.	-0.387*	-0.237	-0.390*	-0.391*
	(0.224)	(0.254)	(0.223)	(0.223)
GDP Growth	-0.000	-0.002	0.000	0.001
	(0.005)	(0.007)	(0.005)	(0.005)
User Cost of R&D	-5.560***	-6.814***	-5.492***	-5.563***
	(0.555)	(0.627)	(0.553)	(0.554)
Real interest rate	-1.382**	-1.882***	-1.338**	-1.276**
	(0.545)	(0.690)	(0.531)	(0.530)
Log no. of affiliates	0.120***	0.110**	0.115***	0.117***
	(0.039)	(0.046)	(0.039)	(0.039)
Log Age	0.088***	0.077***	0.087***	0.088***
	(0.021)	(0.025)	(0.021)	(0.021)
Log Total Assets	0.035***	0.032***	0.036***	0.035***
	(0.005)	(0.006)	(0.005)	(0.005)
Working Capital	0.000	0.000*	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.017***	0.013**	0.017***	0.017***
	(0.005)	(0.005)	(0.005)	(0.005)

This table reports the coefficients of the control variables for the estimations reported in Table 7. Estimation of a Poisson fixed effects model. The dependent variable is the number of new patents per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

Table A.5: R&D Expenditures

	(1)	(3)	(4)	(5)
	Internal R&D Expenditures			External R&D Expenditures
	Total	Experimental	Applied	
BOX_{Haven}	-0.0290	1.491**	-0.603***	-0.893***
	(0.140)	(0.593)	(0.129)	(0.175)
No. of affiliates	0.129*	0.239**	0.049	0.359
	(0.070)	(0.0946)	(0.0942)	(0.297)
Log Age	-0.054	-0.022	-0.077	-0.044
	(0.060)	(0.0766)	(0.114)	(0.175)
Log Total Assets	0.040***	0.239**	0.058***	0.058
	(0.011)	(0.095)	(0.014)	(0.036)
Working Capital	-0.000**	-0.000	-0.000***	-0.008***
	(0.000)	(0.000)	(0.000)	(0.002)
Log Capital Intensity	0.001	0.009	-0.008	0.010
	(0.007)	(0.011)	(0.012)	(0.019)
N	30,134	29,712	29,764	15,625
No. of firms	7,682	7,578	7,593	3,528
Pseudo LL	-1,851,681	-1,833,620	-1,791,755	-782,394

Estimation of a Poisson fixed effects model. The dependent variable are the R&D expenditures in the indicated area per year and firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%. Data source R&D expenditures: SV Wissenschaftsstatistik GmbH, RDC, R&D Survey 2001-2013, own calculations.

Table A.6: Affiliates Consolidated on the Country-level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	No. of new Patents		No. of new Patents (quality-weighted)		No. of new Patents		No. of new Patents (quality-weighted)	
BOX_{Haven}	0.681***		0.634***					
	(0.192)		(0.212)					
$BOX_{Haven} \times \Delta t$		0.023***		0.021***				
		(0.008)		(0.008)				
BOX_{Nexus}					0.013		-0.032	
					(0.033)		(0.034)	
$BOX_{Nexus} \times \Delta t$						0.000		-0.001
						(0.001)		(0.002)
R&D Exp.	0.340***	0.342***	0.457***	0.458***	0.346***	0.347***	0.464***	0.463***
	(0.065)	(0.065)	(0.074)	(0.074)	(0.065)	(0.065)	(0.074)	(0.074)
Log GDP p.c.	-0.488*	-0.488*	0.732***	0.732***	-0.497*	-0.495*	0.729***	0.727***
	(0.254)	(0.254)	(0.260)	(0.260)	(0.255)	(0.254)	(0.260)	(0.260)
CIT	-0.004	-0.004	-0.007**	-0.007**	-0.004	-0.004	-0.006**	-0.007**
	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
GDP Growth	0.002	0.002	-0.011*	-0.011*	0.002	0.002	-0.011*	-0.011*
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
User Cost of R&D	-5.639***	-5.636***	-4.591***	-4.588***	-5.644***	-5.631***	-4.520***	-4.535***
	(0.566)	(0.566)	(0.601)	(0.601)	(0.567)	(0.566)	(0.600)	(0.601)
Real interest rate	-1.189**	-1.187**	-1.556***	-1.554***	-1.179**	-1.177**	-1.534***	-1.535***
	(0.535)	(0.535)	(0.555)	(0.555)	(0.535)	(0.535)	(0.554)	(0.555)
No. of affiliates	0.168***	0.168***	0.158***	0.158***	0.169***	0.169***	0.159***	0.159***
	(0.040)	(0.040)	(0.043)	(0.043)	(0.040)	(0.040)	(0.043)	(0.043)
Log Age	0.115***	0.115***	0.130***	0.130***	0.116***	0.115***	0.127***	0.127***
	(0.022)	(0.022)	(0.024)	(0.024)	(0.022)	(0.022)	(0.025)	(0.025)
Log Total Assets	0.028***	0.028***	0.025***	0.025***	0.028***	0.028***	0.025***	0.025***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Working Capital	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.020***	0.020***	0.017***	0.017***	0.020***	0.020***	0.017***	0.017***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
N	208,348	208,348	202,001	202,001	208,348	208,348	202,001	202,001
No. of firms	18509	18509	17914	17914	18509	18509	17914	17914
Pseudo LL	-107,916	-107,918	-63,495	-63,496	-107,927	-107,927	-63,499	-63,499

Estimation of a Poisson fixed effects model. The dependent variable is the (quality-weighted) number of new patents per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

Table A.7: MNEs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	No. of new Patents		No. of new Patents (quality-weighted)		No. of new Patents		No. of new Patents (quality-weighted)	
BOX_{Haven}	0.656***		0.662***					
	(0.204)		(0.221)					
$BOX_{Haven} \times \Delta t$		0.022***		0.022***				
		(0.008)		(0.008)				
BOX_{Nexus}					0.017		-0.007	
					(0.038)		(0.040)	
$BOX_{Nexus} \times \Delta t$						0.000		-0.001
						(0.002)		(0.002)
R&D Exp.	0.303***	0.306***	0.345***	0.348***	0.315***	0.316***	0.357***	0.356***
	(0.099)	(0.098)	(0.108)	(0.108)	(0.099)	(0.099)	(0.108)	(0.108)
Log GDP p.c.	-0.628	-0.626	0.450	0.450	-0.654	-0.653	0.426	0.422
	(0.474)	(0.473)	(0.505)	(0.505)	(0.476)	(0.476)	(0.508)	(0.508)
CIT	0.001	0.001	-0.004	-0.004	0.001	0.001	-0.004	-0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
GDP Growth	0.002	0.003	-0.005	-0.005	0.003	0.003	-0.005	-0.004
	(0.009)	(0.009)	(0.010)	(0.010)	(0.009)	(0.009)	(0.010)	(0.010)
User Cost of R&D	-1.105	-1.091	-1.599	-1.586	-1.092	-1.080	-1.573	-1.589
	(1.243)	(1.243)	(1.318)	(1.317)	(1.250)	(1.250)	(1.323)	(1.324)
Real interest rate	0.210	0.215	-0.492	-0.488	0.226	0.229	-0.475	-0.476
	(0.888)	(0.888)	(0.935)	(0.935)	(0.888)	(0.888)	(0.934)	(0.935)
No. of affiliates	0.080	0.080	0.071	0.071	0.086	0.084	0.074	0.073
	(0.098)	(0.098)	(0.104)	(0.104)	(0.098)	(0.098)	(0.104)	(0.104)
Log Age	0.110***	0.110***	0.106***	0.106***	0.109***	0.108***	0.105***	0.105***
	(0.038)	(0.038)	(0.041)	(0.041)	(0.038)	(0.038)	(0.041)	(0.041)
Log Total Assets	0.045***	0.045***	0.032***	0.032***	0.045***	0.045***	0.032***	0.032***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Working Capital	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.029***	0.029***	0.029***	0.029***	0.029***	0.029***	0.029***	0.029***
	(0.010)	(0.010)	(0.011)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)
N	53,178	53,178	52,342	52,342	53,178	53,178	52,342	52,342
No. of firms	4,878	4,878	4,799	4,799	4,878	4,878	4,799	4,799
Pseudo LL	-36,727	-36,728	-24,171	-24,172	-36,736	-36,736	-24,176	-24,176

Estimation of a Poisson fixed effects model. The dependent variable is the (quality-weighted) number of new patents per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. The sample only contains MNEs. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

Table A.8: Linear Model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log no. of new Patents		Log no. of new Patents (adjusted)		Log no. of new Patents		Log no. of new Patents (adjusted)	
BOX_{Haven}	0.311***		0.122***					
	(0.117)		(0.035)					
$BOX_{Haven} \times \Delta t$		0.009*		0.004***				
		(0.005)		(0.001)				
BOX_{Nexus}					0.005		-0.010	
					(0.019)		(0.007)	
$BOX_{Nexus} \times \Delta t$						-0.000		-0.001*
						(0.001)		(0.000)
R&D Exp.	0.022	0.024	0.048***	0.049***	0.025	0.026	0.049***	0.049***
	(0.039)	(0.039)	(0.009)	(0.009)	(0.039)	(0.039)	(0.009)	(0.009)
Log GDP p.c.	-0.430***	-0.430***	-0.094***	-0.094***	-0.433***	-0.433***	-0.095***	-0.095***
	(0.122)	(0.122)	(0.026)	(0.026)	(0.122)	(0.122)	(0.026)	(0.026)
CIT	-0.000	-0.000	-0.001	-0.001	-0.000	-0.000	-0.001	-0.001
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
GDP Growth	0.002	0.002	0.000	0.000	0.002	0.002	0.000	0.000
	(0.003)	(0.003)	(0.001)	(0.001)	(0.003)	(0.003)	(0.001)	(0.001)
User Cost of R&D	-0.376	-0.373	-0.760***	-0.759***	-0.376	-0.367	-0.751***	-0.750***
	(0.307)	(0.307)	(0.063)	(0.063)	(0.308)	(0.308)	(0.063)	(0.063)
Real interest rate	-0.340	-0.339	-0.190***	-0.189***	-0.336	-0.335	-0.188***	-0.188***
	(0.346)	(0.346)	(0.067)	(0.067)	(0.346)	(0.346)	(0.067)	(0.067)
No. of affiliates	0.036	0.036	0.016***	0.016***	0.036	0.036	0.016***	0.016***
	(0.022)	(0.022)	(0.006)	(0.006)	(0.022)	(0.022)	(0.006)	(0.006)
Log Age	0.016	0.016	0.014***	0.014***	0.016	0.016	0.014***	0.014***
	(0.013)	(0.013)	(0.003)	(0.003)	(0.013)	(0.013)	(0.003)	(0.003)
Log Total Assets	0.009**	0.009**	0.003***	0.003***	0.009**	0.009***	0.004***	0.004***
	(0.003)	(0.003)	(0.001)	(0.001)	(0.003)	(0.003)	(0.001)	(0.001)
Working Capital	-0.000**	-0.000**	0.000	0.000	-0.000**	-0.000**	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Capital Intensity	0.001	0.001	0.002***	0.002***	0.001	0.001	0.002***	0.002***
	(0.003)	(0.003)	(0.001)	(0.001)	(0.003)	(0.003)	(0.001)	(0.001)
N	49,289	49,289	26,349	263,490	49,289	49,289	263,490	263,490
No. of firms	20,588	20,588	25,110	25,110	20,588	20,588	25,110	25,110
R^2	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004

Estimation of a linear fixed effects model. In columns (1), (2), (5) and (6) the dependent variable is the logarithm of the number of new patents per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. In columns (3), (4), (7) and (8), observations of the dependent variable are replaced by zero if the patent count is zero. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

Table A.9: Probit Regression for PSM

	Ever being treated	Treated in current year
	(1)	(2)
Log Age	-0.028***	-0.011***
	(0.192)	(0.005)
Log No. Affiliates	1.155***	1.081***
	(0.006)	(0.005)
Log Total Assets	0.049***	0.058***
	(0.005)	(0.003)
Working Capital	0.057***	-0.000***
	(0.018)	(0.000)
Log Capital Intensity	-0.044***	-0.012***
	(0.006)	(0.003)
Controls with year 2000 values	✓	
Country-industry FE	✓	✓
Year FE		✓
N	212,009	273,062
Log Likelihood	- 27,534.209	-33,819.778
Pseudo R^2	0.659	0.652

For Propensity Score Matching (PSM), a Probit estimation is conducted. Table A.9 presents the results. In column (1), we regress a dummy equal to 1 if during the sample period a patent box regime without nexus requirement is implemented in a foreign affiliate country on the firm characteristics in the year 2000. Doing so ensures equality of treated firms and untreated firms at the beginning of the treatment period. In column (2), we regress a dummy equal to 1 only in the year if the patent box in the foreign affiliate is implemented in the current year on firm characteristics in the current year. With this specification we aim to find comparables for specific years. Estimation of a Probit model. The dependent variable is a dummy for being treated at least once during the sample period (column 1) or for being treated in the current year (column 2). All regressions include country- and industry-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

Table A.10: Average treatment effect on the treated using matching

	No. of new patents			
	(1)	(2)	(3)	(4)
ATT	0.608***	0.637***	0.804**	0.277***
	(0.199)	(0.058)	(0.402)	(0.035)
PSM	✓	✓		
CEM			✓	✓
Matched on initial firm characteristics	✓		✓	
Matched on yearly firm characteristics		✓		✓

ATT denotes 'average treatment effect of the treated'. The calculation of the ATT includes firm-fixed effects if feasible (columns 1 and 3). Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

References

Aghion, Philippe, Reenen, John Van, & Zingales, Luigi. 2013. Innovation and Institutional Ownership. *American Economic Review*, **103**(1), 277–304.

Alstadsater, Annette, Barrios, Salvador, Nicodème, Gaëtan, Skonieczna, Agnieszka, & Vezzani, Antonio. 2015. *Patent boxes design, patents, location and local R&D*. Working Paper 15/18. Oxford University Centre for Business Taxation.

Becker, Johannes, Fuest, Clemens, & Riedel, Nadine. 2012. Corporate tax effects on the quality and quantity of FDI. *European Economic Review*, **56**(8), 1495–1511.

Bena, Jan, & Li, Kai. 2014. Corporate innovations and mergers and acquisitions. *The Journal of Finance*, **69**(5), 1923–1960.

Bloom, Nick, Griffith, Rachel, & Van Reenen, John. 2002. Do R&D tax credits work? Evidence from a panel of countries 1979–1997. *Journal of Public Economics*, **85**(1), 1–31.

Blundell, Richard, Griffith, Rachel, & Van Reenen, John. 1995. Dynamic count data models of technological innovation. *The Economic Journal*, **105**(429), 333–344.

Bollaert, Helen, & Delanghe, Marieke. 2015. Securities Data Company and Zephyr, data sources for M&A research. *Journal of Corporate Finance*, **33**, 85–100.

Bradley, Sebastien J, Dauchy, Estelle, & Robinson, Leslie. 2015. Cross-Country Evidence on the Preliminary Effects of Patent Box Regimes on Patent Activity and Ownership. *National Tax Journal*, **68**(4).

Bräutigam, Rainer, Spengel, Christoph, & Streif, Frank. 2017. Decline of CFC Rules and Rise of IP Boxes: How the European Court of Justice Affects Tax Competition and Economic Distortions in Europe. *Fiscal Studies*.

Cameron, A Colin, & Trivedi, Parvin K. 2015. Count Panel Data. *In:* Baltagi, Badi H. (ed), *The Oxford Handbook of Panel Data*. Oxrford University Press.

Chen, Shannon, De Simone, Lisa, Hanlon, Michelle, Lester, Rebecca, *et al.* 2016. *The Effect of Innovation Box Regimes on Income Shifting and Real Activity*. Working Paper No. 3453.

Chetty, Raj, Friedman, John N., Leth-Petersen, S?ren, Nielsen, Torben Heien, & Olsen, Tore. 2014. Active vs. Passive Decisions and Crowd-Out in Retirement Savings Accounts: Evidence from Denmark. *The Quarterly Journal of Economics*, **129**(3), 1141–1219.

Ciaramella, Laurie. 2017. *Patent Boxes and the Relocation of Intellectual Property*. SSRN Working Paper 2943435.

Cravino, Javier, & Levchenko, Andrei A. 2017. Multinational firms and international business cycle transmission. *The Quarterly Journal of Economics*, **132**(2), 921–962.

Desai, Mihir A, Foley, C Fritz, & Hines, James R. 2006. Do tax havens divert economic activity? *Economics Letters*, **90**(2), 219–224.

Dharmapala, Dhammika. 2008. What problems and opportunities are created by tax havens? *Oxford Review of Economic Policy*, **24**(4), 661–679.

Dischinger, Matthias, & Riedel, Nadine. 2011. Corporate taxes and the location of intangible assets within multinational firms. *Journal of Public Economics*, **95**(7), 691–707.

Ernst, Christof, Richter, Katharina, & Riedel, Nadine. 2014. Corporate taxation and the quality of research and development. *International Tax and Public Finance*, **21**(4), 694–719.

Evers, Lisa, Miller, Helen, & Spengel, Christoph. 2015. Intellectual property box regimes: effective tax rates and tax policy considerations. *International Tax and Public Finance*, **22**(3), 502–530.

Gaessler, Fabian, Hall, Bronwyn H, & Harhoff, D. 2017. *Patent boxes and patent transfers.* mimeo.

Granger, Clive WJ. 1969. Investigating causal relations by econometric models and cross-spectral methods. *Econometrica: Journal of the Econometric Society*, 424–438.

Griffith, Rachel, Miller, Helen, & O'Connell, Martin. 2014. Ownership of intellectual property and corporate taxation. *Journal of Public Economics*, **112**, 12–23.

Guellec, Dominique, & de la Potterie, Bruno van Pottelsberghe. 2001. The internationalisation of technology analysed with patent data. *Research Policy*, **30**(8), 1253–1266.

Hagedoorn, John, & Cloodt, Myriam. 2003. Measuring innovative performance: is there an advantage in using multiple indicators? *Research Policy*, **32**(8), 1365–1379.

Hall, Bronwyn H., Thoma, Grid, & Torrisi, Salvatore. 2007 (September). *The market value of patents and R&D: Evidence from European firms.* NBER Working Paper 13426. National Bureau of Economic Research.

Hall, Bronwyn H, Mairesse, Jacques, & Mohnen, Pierre. 2010. Measuring the Returns to R&D. *Chap. 24, pages 1033–1082 of:* Hall, Bronwyn H., & Rosenberg, Nathan (eds), *Handbook of the Economics of Innovation*, vol. 2. Elsevier.

Hall, Robert E, & Jorgenson, Dale W. 1967. Tax policy and investment behavior. *The American Economic Review*, **57**(3), 391–414.

Harhoff, Dietmar, Narin, Francis, Scherer, Frederic M, & Vopel, Katrin. 1999. Citation frequency and the value of patented inventions. *Review of Economics and statistics*, **81**(3), 511–515.

Haufler, Andreas, & Stähler, Frank. 2013. Tax Competition In A Simple Model With Heterogeneous Firms: How Larger Markets Reduce Profit Taxes. *International Economic Review*, **54**(2), 665–692.

Hausman, Jerry, Hall, Bronwyn H., & Griliches, Zvi. 1984. Econometric Models for Count Data with an Application to the Patents-R&D Relationship. *Econometrica*, **52**(4), 909–938.

Heckemeyer, Jost, Richter, Katharina, Sch?tzler, Margarete, Schmidt, Frank, & Spengel, Christoph. 2015. *A Survey of Taxation and Corporate Innovation.* Report. PricewaterhouseCoopers.

Hong, Qing, & Smart, Michael. 2010. In praise of tax havens: International tax planning and foreign direct investment. *European Economic Review*, **54**(1), 82–95.

Hoynes, Hilary, Page, Marianne, & Stevens, Ann Huff. 2011. Can targeted transfers improve birth outcomes?: Evidence from the introduction of the WIC program. *Journal of Public Economics*, **95**(7), 813–827.

Jacob, Jojo. 2013. PATSTAT database for patent-based research. *Innovation and Development*, **Volume 3**.

Karkinsky, Tom, & Riedel, Nadine. 2012. Corporate taxation and the choice of patent location within multinational firms. *Journal of International Economics*, **88**(1), 176–185.

King, Gary, & Nielsen, Richard. 2015. *Why propensity scores should not be used for matching.* mimeo.

Kline, Patrick. 2012. The Impact of Juvenile Curfew Laws on Arrests of Youth and Adults. *American Law and Economics Review*, **14**(1), 44.

Koethenbuerger, Marko, Liberini, Federica, & Stimmelmayr, Michael. 2016. *Is it Luring Innovations or just Profit? The Case of European Patent Boxes.* mimeo.

Lanjouw, Jean O, & Schankerman, Mark. 2004. Patent quality and research productivity: Measuring innovation with multiple indicators. *The Economic Journal*, **114**(495), 441–465.

Mamuneas, Theofanis P, & Nadiri, M Ishaq. 1996. Public R&D policies and cost behavior of the US manufacturing industries. *Journal of Public Economics*, **63**(1), 57–81.

Melitz, Marc, Helpman, Elhanan, & Yeaple, Stephen. 2004. Export versus FDI with heterogeneous firms. *American Economic Review*, **94**(1), 300–316.

OECD. 2015. *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development*. Vol. 6. Paris: OECD Publishing.

Seru, Amit. 2014. Firm boundaries matter: Evidence from conglomerates and R&D activity. *Journal of Financial Economics*, **111**(2), 381–405.

Slemrod, Joel, & Wilson, John D. 2009. Tax competition with parasitic tax havens. *Journal of Public Economics*, **93**(11), 1261–1270.

Stiebale, Joel. 2016. Cross-border M&As and innovative activity of acquiring and target firms. *Journal of International Economics*, **99**, 1–15.

Thomson, Russell. 2013. Measures of R&D Tax Incentives for OECD Countries. *Review of Economics and Institutions*, **4**(3), 1–35.

Warda, Jacek. 2002. *Measuring the Value of R&D Tax Treatments in OECD Countries*. STI Review No. 27. OECD.

Wilson, Daniel J. 2009. Beggar thy neighbor? The in-state, out-of-state, and aggregate effects of R&D tax credits. *The Review of Economics and Statistics*, **91**(2), 431–436.

Wooldridge, Jeffrey. 2010. *Econometric Analysis of Cross Section and Panel Data: Second Edition*. Vol. 2. MIT Press.

Wooldridge, Jeffrey M. 1999. Distribution-free estimation of some nonlinear panel data models. *Journal of Econometrics*, **90**(1), 77–97.

2013

2013/1, Sánchez-Vidal, M.; González-Val, R.; Viladecans-Marsal, E.: "Sequential city growth in the US: does age matter?"
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2013/23, Costa-Campi, M.T.; Duch-Brown, N.; García-Quevedo, J.: "R&D drivers and obstacles to innovation in the energy industry"
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2014

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